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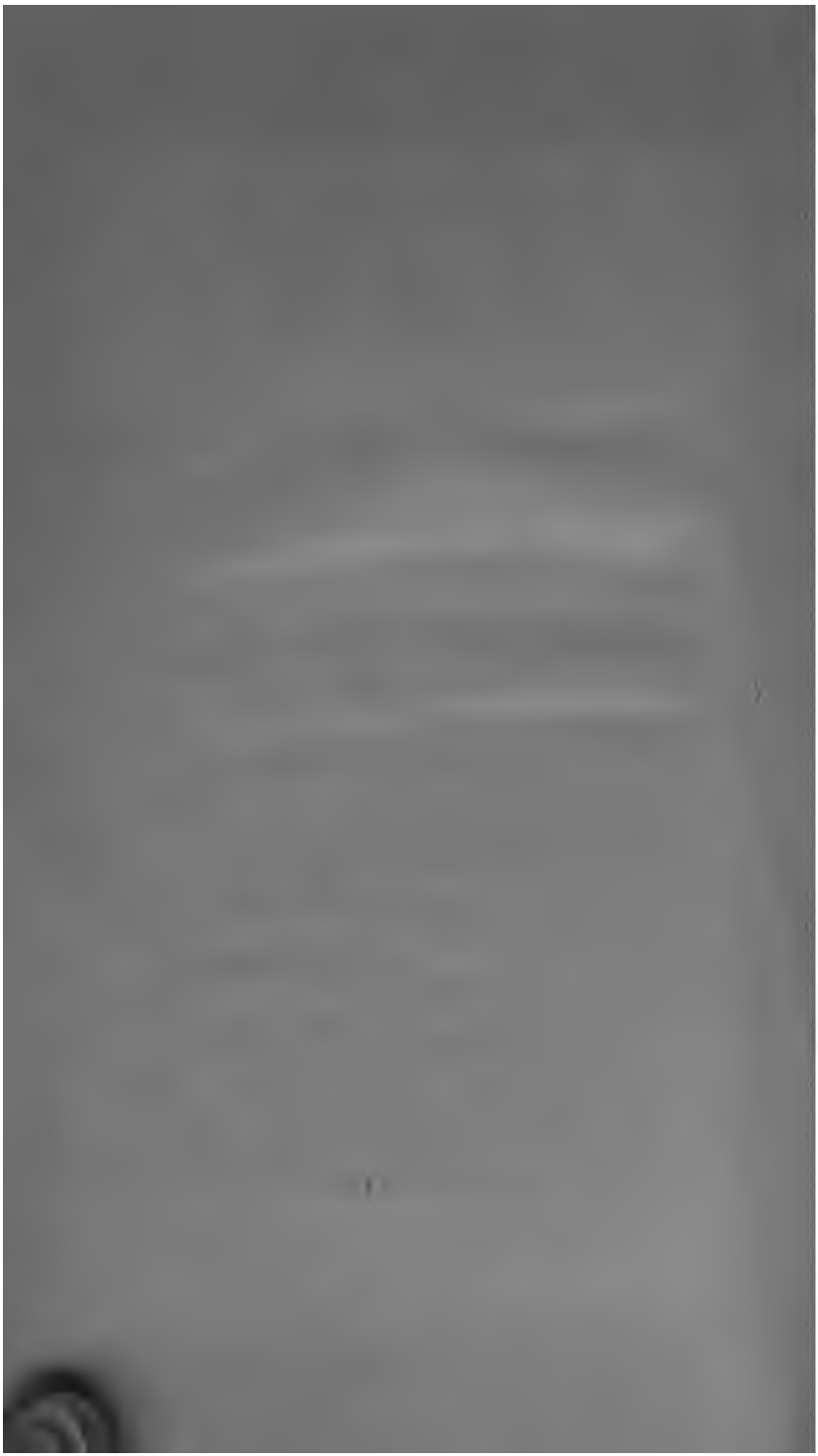
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PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE SIXTEENTH,

1874-5.

(The Authors having revised their own papers, are alone responsible for the facts and opinions expressed in them.)

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Liverpool Geological Society.

SESSION SIXTEEN TO NINETEEN,

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THE PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION SIXTEENTH.

OCTOBER 13TH, 1874.

THE PRESIDENT, ISAAC ROBERTS, F.G.S., in the Chair.

ALLEN GREEN was elected an Ordinary Member.

The President read the Annual Address.

PRESIDENT'S ADDRESS.

ONE of the most important subjects that is now prominently occupying the attention of geologists, is the investigation of the superficial deposits that are scattered far and wide, and (at first sight) without any apparent order, over large portions of the surface of the globe.

The study of the rock formations upon which the deposits here referred to rest, has been diligently and successfully pursued for more than half a century, by energetic and zealous workers, and they have furnished us with elaborate memoirs and carefully prepared treatises concerning the several divisions and sub-divisions

into which those rock formations have been classified. But the systematic study of the superficial deposits has been reserved chiefly for the present time; and we have, since the close of our last Session, been presented by Mr. James Geikie, F.R.S.E., F.G.S., with a thick volume of matter, by the aid of which we may place ourselves in an advanced position for understanding the difficult and complex phenomena which those superficial deposits present to those who attempt to investigate them.

Glacial Drift is the name given to most of those loose, incoherent materials which cover large areas in this and other countries. The Glacial Drifts are, (like the rock formations,) found to represent several long successive intervals of time and conditions of climate during their deposition. Their faunæ at one time indicate a severe arctic climate. That was followed by a temperate, if not a tropical climate; later still, the land was submerged beneath the sea; again it rose, under a mild climate, was clothed with vegetation, inhabited by animals, man probably being amongst the number. The mild climate was succeeded by another arctic climate, which, in its turn, gave place to the existing order of things. But I intend to deal moderately on this occasion with speculation, and present to you instead, as far as the very brief time at my disposal will permit, some of the evidence upon which the inferences I have just stated are founded.

I therefore propose to describe some of the beds which are generically termed the Glacial Drifts; and, after examining some of their physical properties, pass on to cold, and arctic, and antarctic regions, to describe the forces of Nature which are now in operation, producing phenomena similar to those which we can trace in the Drifts. We will examine the Drifts in

the order of super-position which the experience of many geologists in this and other countries has now assigned to them; but we must not assume that this arrangement of super-position is final, for as the work of examination and co-relation proceeds, probably modifications will be made in both the order and number of the beds.

Mr. Geikie, in his "Great Ice Age," says that in Scotland are found good typical examples of successive Glacial Deposits, and these he co-relates with the Drifts of other countries. The lowest or oldest of the deposits is the TILL, and is described by him as "Usually a firm, tough, tenacious, stony clay. So tough, indeed, does it often become, that engineers would much rather excavate the most obdurate rocks. Hard rocks are more or less easily assailable with gunpowder, and the numerous joints and fissures by which they are traversed enable the navvies to wedge them out, often in considerable lumps. But Till has neither crack nor joint; it will not blast, and to pick it to pieces is a very slow and laborious process. Occasionally, however, the clay becomes coarser and sandier, and when this is the case water soaks through it. It then loses consistency, and is ready to 'run' or collapse as soon as an excavation is made. Sometimes the stones in the Till are so numerous that hardly any matrix of clay is visible. This, however, does not often happen. On the other hand, they occasionally appear more sparsely scattered through the clay, which may then be dug for brick-making; but this occurs still less frequently. As a rule, it is hard to say whether the stones or the clay form the larger share percentage of the deposit, in a mass of typical Till. Generally speaking, however, the stones are most numerous in the Till of hilly districts; while at the lower levels of the

country the clayey character of the mass is, on the whole, more pronounced; but to this there are many exceptions.

"The stones vary in size, from mere grit and pebbles up to blocks several feet, or even yards, in diameter. These last, however, do not occur so commonly as smaller stones; indeed boulders above four feet in diameter are comparatively seldom met with in the Till. Stones and boulders alike are scattered higgledy-piggledy, pell-mell, through the clay, so as to give to the whole deposit a highly confused and tumultuous appearance. There is something very peculiar about the shape of the stones. They are neither round and oval, like the pebbles in river gravel, or the shingle of the sea shore, nor are they sharply angular, like newly-fallen débris at the base of a cliff, although they more closely resemble the latter than the former. They are, indeed, angular in shape; but the sharp corners and edges have been invariably smoothed away. Each is smoothed, polished, and covered with striæ, or scratches, some of which are delicate as the lines traced by an etching-needle, others deep and harsh as the scores made by a plough upon a rock; and, what is also worthy of note, most of the scratches, coarse and fine together, seem to run parallel to the longer diameter of the stones; which, however, are scratched in many other directions as well."

The Till is quite local in character; for in districts where sandstone occurs most abundantly, the stones in the clay likewise consist almost exclusively of sandstone. And, similarly, in regions where hard volcanic rocks prevail, the overlying Till is invariably crowded with fragments of the same. Not only the stones, however, but also the colour and texture of the clay itself, are influenced by the character of the rocks in whose neighbourhood the Till occurs. Thus, in a district where the

rocks consist chiefly of dark shales, clays, and thin sandstones, with occasional seams of coal, the overlying Till is usually hard and tough, and its prevailing colour a dark, dingy grey, or dirty blue; while in a region of Red Sandstone it is tinted red or brown, and commonly shows a more open or sandier texture. Remains of the great woolly elephant, or mammoth, and the reindeer, and fragments of various kinds of trees, such as pine, birch, and oak, have occasionally been found in the Till, in which they appear precisely in the same manner as stones or boulders; but not a single *trace of any marine organism* has yet been detected in true Till.

It is in the lower lying districts of the country where the Till appears in greatest force. Wide areas of the central counties are covered with it continuously, to a depth varying from two or three feet up to one hundred feet and more, and it is distinctly *un*stratified; it is a homogeneous mass from top to bottom. But, although this is the invariable character of the Till itself, it nevertheless contains, here and there, more or less regular beds of gravel, sand, silt, mud, and brick-clay, and occasionally similar deposits underlie the Till, and separate that deposit from the subjacent solid rocks.

The next deposit above the Till is the Boulder-clay. This appears to be limited to maritime districts. In many respects, the composition of the Boulder-clay resembles that of the Till so closely that it is difficult, if not impossible, to distinguish one from the other. But, unlike the Till, it presents in parts distinct bedding. It also differs from the Till, in having the contained stones and boulders more rounded, less scratched, and smaller in size. It also frequently contains marine shells, generally in a broken state.

There are, in and around Liverpool, very extensive

areas covered with Boulder-clay; and, from the frequent opportunities afforded for examining them in excavations for foundations of buildings, trenches for sewers, tanks for gas-holders, docks, and cliffs fifty or sixty feet in height, along both sides of the River Mersey, its characteristic features have been studied by several members of this Society; and the results of their investigations have from time to time been published in the "Proceedings" of the Society.

I bring before you this evening specimens of the Boulder-clay in its natural state, and also separated into its constituent parts.

The microscope slide marked A shows that portion of the clay which, when washed with water, remains for a very long time in suspension, giving the water a slightly turbid appearance. Viewed under the microscope, it is resolved into transparent globules or crystals, some of which are probably lime and alumina. The next slide, marked B, contains what is shown on slide A, together with rocky matter, in a very finely divided state. The next slide, marked C, shows the clay separated into an impalpable powder, and also into grains of sand which are just visible to the eye. The next slide, marked D, shows the clay separated into coarser grains of sand, which show the characteristic features of the various rocks which have been ground down to form the Boulder-clay. In the drawer on the table are larger specimens of the same rocks, some of which show striæ; but the great mass of the Boulder-clay of this locality seems to be composed of the ground-up Keuper shales and Bunter sandstones.

In the drawers which are now before you are specimens of the shells which have been picked out of the Boulder-clay; and you will observe that the shells of the

species *Turritella communis* form by far the larger proportion of the shells found in the clay. Many of them are in a very perfect state, with the point of the shell as sharp as the point of a bodkin.

The whole of the shells in these drawers were picked from two excavations made in the Boulder-clay, each about 150 feet in diameter and 33 feet in depth below the surface. They may be considered roughly to represent the relative proportions, varieties, and numbers of the shells found in the Boulder-clay, in the neighbourhood of Liverpool, and might be adopted as a rough basis for calculation of the number of shells that might be found in any given similar area and depth.

I have already described the shells here referred to before this Society, and for further details refer you to the Proceedings for Session 1870-71. I have also found similar shells to these at Wavertree; on the shores of the Mersey; at Toxteth Park, New Ferry and Egremont. I would also refer you to the list of shells given by Mr. Morton, F.G.S., in the "Proceedings" for last Session, and one by Mr. T. Mellard Reade, F.G.S., in the "Quarterly Journal of the Geological Society," vol. 30.

Mr. C. E. de Rance, F.G.S., who, in the "Quarterly Journal of the Geological Society" (vol. 26, page 1), has given a slight sketch of the bank of clay at Egremont, has divided it into upper and lower Boulder-clay, with middle Drift-sand between. But, after examining wide areas of Boulder-clay in and around Liverpool during a period of more than twenty years, and with many opportunities of seeing excavations for wells and other purposes made deeply into and through the Boulder-clay, I have failed to discover any conclusive evidence that the Boulder-clay of this neighbourhood is geologically divisible into upper and lower, with Drift-sands between.

I have frequently seen local patches of sand imbedded in the Boulder-clay; and, if these can be proved to be the lowest remnants of Middle Drift Sands, which were deposited, and then denuded, leaving only these patches as evidence of that deposition, Mr. de Rance's statement would be established; but I think we require clearer evidence than we yet possess, to establish the theory.

The sandstone rocks which underlie the Boulder-clay in places where they have been exposed to view, are found to be planed to a comparatively even surface, and that surface is distinctly grooved and striated.

Mr. James Geikie* gives several sections of the Boulder-clay, as it is seen in Scotland. The following, at Lewis, will serve as an example :—

1. Boulder-clay.
2. Sand, gravel, and coarse shingle, with rolled and angular fragments of shells.
3. Dark bluish brown clay and silt, with shells, many of them mere fragments.
4. Boulder-clay, with broken shells.

The Boulder-clay is sometimes partially stratified; at other times it contains beds, bands, and layers of sand, gravel, and clay, in which shells, or fragments of shells, are not unfrequently detected. Again, it passes into a regular stony clay, which it is difficult, or even impossible to distinguish from the Till of the interior.

The period which succeeded the deposition of the Boulder-clay, is marked by large accumulations of sands, gravels, and erratic blocks, widely scattered over the surface of the country, and often occurring at heights of more than 1,000 feet above the level of the sea. These accumulations are found resting sometimes on bare rock, sometimes on the Till, sometimes on the Boulder-clay, and

* "The Great Ice Age," p. 211.

sometimes the erratic blocks are found in and upon the mounds or "kames" of sand and gravel.

Time will not permit me to trace in detail the deposits which are of more recent origin than those already described. We shall, therefore, pass on to the regions of great ice and snow, to see how far the forces of Nature which are now in operation there, can be shown to be producing phenomena similar to those which we have already noted in the Drifts.

There we shall see that most of the phases presented to us in studying the Drifts, can be accounted for, without having recourse to cataclysms and other irregular interference with what we observe to be the laws of Nature.

The chief difficulty that meets us at the threshold of our investigation is, how to realise to ourselves the magnitude of the changes that are constantly in progress by the action of snow and ice, such as now exist, in the Arctic and Antarctic regions. But to help us in this difficulty, I refer you to three drawings, which are exhibited on the wall, and marked respectively A, B, and C, and also the photographs in the book. The drawing marked A is an enlarged sketch of one published in Sir J. C. Ross' voyage to the Antarctic regions, in 1839–43. It represents a barrier of ice, or end of a *mer de glace*, which probably covers the whole of those regions as far as lat. 60° to 65° S. It was traced in an unbroken wall for a length of 450 miles, and it is at least 1,000 feet in average thickness, and 180 feet above the level of the sea.

The drawing marked B is enlarged from a sketch by H. M. Skae, in Mr. Geikie's work, "The Great Ice Age," and represents one of the Greenland glaciers; one of which, called the Humboldt Glacier, is 60 miles in breadth at its termination, and its seaward height

measures 300 feet; its depth is unknown, but, assuming that it is immersed to the extent of seven-eighths its height, that being the approximate proportion of iceberg flotation, its total thickness would be 2,400 feet.

The drawing marked C is an imaginary sketch of the end of a glacier, when it has proceeded so far out to sea that its buoyancy is sufficient to snap off the end, to form icebergs. That takes place suddenly, and is accompanied by sounds like the roar of cannon, and by extensive disturbance of the sea for considerable distances. The photographs in the book called "The Oberland and its Glaciers" show the general appearance of inland glaciers, and their terminal moraines.

It is only a few years since the discovery was made that glaciers are not inert accumulations of snow and ice; and still more recent is the discovery of the cause of glacier motion; and that it is a powerful force contributing largely to the physical changes that modify and re-arrange the surface of the Earth.

It is now known that glaciers move by the combined energies of heat, gravitation, and crystallisation. Heat dissolves the snow or ice on the surface of the glacier; the water, thus liberated from the crystalline state, shrinks in volume and finds its way to a lower level in the mass of the glacier by the influence of gravity. There it is re-crystallised, and expands in volume, exerting at the same time a pressure on the adjoining particles of ice; these are forced to move, so as to make room for the new crystals; and thus, throughout the length, breadth, and thickness of the glacier is the alternate solution and re-crystallisation of the molecules of water, made the power by which the glacier is forced to move, even along a level plain.

The work done in grinding and removing the floor

upon which the glacier moves will be proportional to its depth or weight, its rate of motion, the yielding nature of the floor, and number of pieces of hard rock attached to the underside of it, which act as grinders or rubbers.

In order fully to realise the extent of the changes effected by glacier action in the present time, it is necessary to visit the Arctic and Antarctic regions; and, furtunately for us, many bold navigators and scientific men, amongst whom I will mention Ross, Parry, and Franklin, have already done so, and have furnished us with data and vivid descriptions of what they have seen, from which we may draw inferences. The icefields of the temperate zones have also been carefully studied, and the results laid before us. From all these sources we may form an idea of the gigantic operations which are constantly being performed under the influence of alternate heat and cold, in breaking up, grinding, selecting, and re-distributing the rocks and materials which form the surface in those regions.

The whole of the land within and beyond the Arctic Circle, which is covered with snow and ice, is subjected to the grinding process of a heavy, slow-moving continent of ice, which, with its imbedded stones, scours even the hardest rocks into gravel, sand, and impalpable mud, which the running water of dissolved snow and ice carries to the sea from beneath the glaciers, and which the sea distributes far and wide, and arranges according to the size and weight of the respective particles, and force of the currents and waves.

From beneath the ice continents and glaciers, which cover the Arctic and Antarctic regions, as indicated by the paper caps which are placed on the globe before you, flow immense rivers of water, formed by the ice and snow, which been have melted by the heat of the sun

in summer, and by the heat of the rocks beneath. These rivers are turbid, or muddy, with the spoil of the rocks which have been ground by the ice in motion. At last the mud reaches the sea, and is distributed in a gentle slope over the sea-bottom.

Along with the mud the moving ice pushes stones of all sizes, striated and rounded, which it has used as rubbers to scour down the rock-bed upon which it slides, but which rubbers it had not time to use up entirely in the process of grinding. They are, therefore, ejected at the foot of the ice, and form a sub-marine *moraine*; and, as the foot of the ice advances and retreats for many miles with the alternations of the winter and summer temperatures in the regions of the ice and snow, the stones of the *moraines* are, in like manner, pushed along the sea-bottom over the deposits of fine mud; and thus they get mixed with the mud, as we see by examination was done during the deposition of the Boulder-clay of this and other localities.

This is not the only mode in which Glacial deposits are now distributed, for we find in cold climates that the margins of the seas are frozen in winter, and in summer these margins break up and float away to sea, carrying, with the materials which have been frozen to the underside of them, vast quantities of *débris* which have fallen upon their surface from the cliffs which form the boundaries of the shore margins. There are also Glacier rivers which carry immense quantities of mud out to sea.

Thus we arrive at the present state of our knowledge concerning the Glacial Drifts, and we may now be able to follow and appreciate the inferences which have been drawn from the study of those Drifts.

I have already, in describing the Till, referred to

several beds of gravel, sand, silt, mud, and brick clay, which are intercalated, or deposited, in the Till at different horizons. These beds are accounted for by the theory that, during the deposition of the Till and Boulder-clay, which indicate a severe Arctic climate, with great confluent glaciers stretching far out to sea, there were intermediate periods of mild climate, when corresponding floræ and faunæ flourished. During the Boulder-clay period the land would appear to have stood lower, relative to the sea, than it does now; but what was the extent of the submergence we cannot tell, the upper limits of the Boulder-clay not having been precisely determined. No Boulder-clay, however, has yet been noticed higher than 200 or 260 feet above the sea, and generally it occurs at much lower levels.

The climate and condition of the glaciers during the deposition of the Boulder-clay, may be considered as somewhat similar to the conditions that now prevail at Greenland. "Great Glaciers reached the sea and presented steep faces of ice to the swell of the Atlantic; but between the glacier valleys were long stretches of rocky coast line, fringed with a thick shelf of ice like that which flanks the shores of many regions that border on the dreary Arctic Ocean."

Coast ice and bergs floated about, and the bottom of the sea was tenanted by Arctic Mollusca.

During the deposition of the morainic gravels and stones, which succeeded the Till and Boulder-clay periods, the intense Glacial climate was ameliorating, and the British Islands were elevated above the sea and joined to the Continent.

At that time Mr. Geikie fixes the age of the cave deposits, river gravels, with flint implements imbedded. After the period of the morainic gravels the land was

submerged to a depth of about 2,000 feet below the sea, and the high level beaches were there formed.

Following this was another Arctic climate, but less severe than the former, when the valley moraines, dilluvium, of the south of England, sand, and brick-clay were deposited. After that the land was again elevated, with a cold, temperate climate, following which there was another partial submergence of the land, when the ancient forests were destroyed and peat-beds formed, in which are found relics of man. After the partial submersion I have just referred to, there was another partial re-elevation, which brings us to the existing state of the northern hemisphere.

The question may now be asked, How came England to be involved in an Arctic climate? Mr. Darwin,* who visited South America in 1834, will help us to answer. He describes immense glaciers which flow to the sea from Tierra del Fuego, where the mountains in the interior are only some 4300 feet in height, and the latitude is only as far south as the Cumberland Hills in this country are north. At St. Cruz, in the Cordillera, similar glaciers are met with, and the latitude is only as far south as the southern extremity of Cornwall is north.

If, then, we could find a cause that would transfer the present climate of the southern hemisphere to the northern, we should have the climate of Britain like that of Greenland. and if the cold were a little more severe than that, we should have the coldest period of the Glacial Drift. If a few degrees of cold were transferred from the southern hemisphere to the northern, all the glacial conditions would be attained. That this has been accomplished again and again we have strong evidence to show, and that even Greenland has had a temperate

* "Surveying Voyages to South America," 1839. Vol. 3., p. 280 285.

climate its buried floræ and faunæ show. We also have ample evidence that the climate of England has changed more than once from tropical to Arctic and from Arctic to temperate again; but it would occupy too much of your time on the present occasion to discuss at large the causes which may have brought about the great changes of climate that I have referred to. I shall, therefore, only refer very briefly to one or two of the more striking theories which have been propounded to account for these.

Sir Charles Lyell thinks that the changes in the relative distribution of land and sea would account for the phenomena. We know that the land is constantly being degraded by the action of the various forces of Nature, and spread out again under the sea, and then uplifted by volcanic agencies. Consequently, the continents shift their position, and when there is much land within the tropics, much heated air would result and pass away in great volumes towards the poles, and so ameliorate the polar climates. On the other hand, when there is much land in the temperate zones and at the poles, and less within the tropics, the polar climates would be more severe, and the severity would extend to the temperate zones. But although these theories are supported by so great an authority, their acceptance is only partial. They do not carry conviction to the mind by fully accounting for the phenomena.

The other theory to which I will refer is the astronomical, and the expounders are Mr. Adhémar and Mr. Croll. It is an astronomical fact that the orbit of the earth is an ellipse, the sun being in one of the foci. It is also a fact that in our time the southern hemisphere of the earth is turned towards the sun, and traverses that part of its orbit which is nearest the sun

during our winter months; but in 10,500 years hence the reverse of this will be the case, for then the northern hemisphere will be exposed to the same conditions as the southern is now; and in 21,000 years hence the northern hemisphere will be just in the same relative position that it is in now. The effects of these changes, which are caused by the precession of the equinoxes, will be, it is inferred, that in 10,500 years from this time the climate of the northern hemisphire will be as severe as the climate of the southern hemisphere is now; and that England, if it should then be known by that name, will be undergoing another glacial climate.

It is also inferred that the precession of the equinoxes and eccentricity of the earth's orbit would, at their maximum, produce great caps of ice at the poles alternately; and that these would displace the earth's centre of gravity, and so cause the waters of the seas to rise higher towards the poles. This, in effect, would be the same as a depression of the land, which appears to have occurred more than once during the deposition of the Glacial Drifts.

In considering the temperate and polar climates, we must not omit to take into account the effects produced by the great ocean currents, such, for instance, as the Gulf stream, and there are others equally great. These streams convey a large amount of solar heat from the tropics towards the poles, and in their course materially modify the climate in many countries which are contiguous.

I hope that I have now said enough to induce those who have not hitherto studied the phenomena of the Glacial Drift to induce them to turn their thoughts into this prolific and profitable field of enquiry.

NOVEMBER 10TH, 1874.

THE VICE-PRESIDENT, R. A. ESKRIGGE, F.G.S., in the Chair.

JAMES PATERSON, THOMAS HATHAWAY, C.E., EDWARD W. B. M. HANCE, L.L.B., GEORGE JEVONS, Jun., JAMES KERSHAW, and THOMAS DIXON were elected Ordinary Members.

The following communication was read:—

OBSERVATIONS ON THE GEOLOGY OF THE CHESHIRE SHORE, WITH REMARKS ON THE SUBJECTS NOTICED BY THE MEMBERS OF THE SOCIETY DURING THEIR LAST VISIT.

BY CHARLES POTTER.

DECEMBER 8TH, 1874.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

JAMES L. MCCLAY was elected an Ordinary Member.

The following communication was read:—

THE GLACIAL AND POST-GLACIAL DEPOSITS OF GARSTON AND THE SURROUNDING DISTRICT, WITH REMARKS ON THE STRUCTURE OF THE BOULDER-CLAY,

BY T. MELLARD READE, C.E., F.G.S.

IN my paper on "The Post-Glacial Geology of Lancashire," published in our Proceedings, Session 1871-72, there is a section of a brook disclosed by the dock

excavations at Garston.* Since this section was drawn I have made frequent visits to the excavations, and propose now to describe the results of my observations.

Base of the Deposits.

The whole series of deposits rest upon a floor of rock (Bunter Pebble Beds), shelving at a gradual inclination westward, the *strike* of this slope being approximately parallel with the direction of the River Mersey at Garston. Considering that it is cut out of beds dipping 18° W of N, this floor is remarkably regular.

Ground Moraine.—Resting upon this base is a bed of rocky *débris*, varying from a few inches to two or three feet thick, consisting of red sand ground out of the bed rock, with embedded masses of rubble. This bed, I have elsewhere stated, I consider to be the ground moraine of the great Ice Sheet, representing the maximum intensity of the Glacial Period and the equivalent of the true Scotch Till.† It is a local deposit, varying with the rock it rests upon, and never containing travelled stones. In the section of the Liverpool Extension Railway, disclosing deposits continuous with those bared by the dock excavations, it was also to be seen where the rock was reached, and the Widnes borings also proved it at a depth of 140 feet below ordnance datum in the ancient bed of the river.‡ From the nature of the rock, no groovings or striations were to be met with, and I invariably find them absent where the rock is covered by this deposit.

Erratic Blocks.—Upon the preceding bed erratic or travelled stones and pebbles frequently rest; and, in some cases, large blocks. These do not differ, either in the

* Plate 4, Sec. No. 24.

† "Quarterly Journal of the Geological Society," February 1874.

‡ "Buried Valley of the Mersey."—*Pro. Liverpool Geol. Soc.*, 1872-73.

character of the rocks, or appreciably in the proportions in which they occur, from those distributed through the overlying Boulder-clay. Many blocks of Granite, Syenite, and Greenstone resting upon this sand were to be seen in the railway cutting near St. Mary's Road. Nearer to Warrington the Carboniferous rocks become more frequent. The larger number of these blocks, both in the dock and railway cutting, showed signs of glaciation; and, from the manner in which many were planed, polished, and striated, had evidently been shaped in the Glacier bottom. Coast ice would be incapable of shaping them. I should estimate the largest blocks at about two tons. Where the overlying Boulder-clay is denuded, as at Stanley Road, near Miller's Bridge, these blocks are frequently met with.

The Low Level Marine Boulder-Clay and Sands.—Super-imposed upon the ground moraine, or, where that is absent, the rock itself, is the deposit I have ventured elsewhere to term the "Low Level Marine Boulder-clay and Sands." It is a series of continuous deposits, reaching in the Buried Valley of the Mersey under the town of Widnes to a maximum depth of 163 feet below the surface, and to 169 feet in a well-sinking at Hooton Station, in Cheshire.* As a rule, the deposit I estimate to range from 10 to 50 feet thick over a large area of the country; though in places it is denuded to a few feet, and in some, such as rocky knolls, absent altogether. The bottom beds of the deposit are often hard and coherent, having incorporated with them a large proportion of the red sand from the bed below. In other cases, resting upon the smoothed surface of the rock, it differs little from the mass of the brown-red clay forming the bulk of the deposit above, and familiar to us all as the brick-making

* The depths of these deposits are given in my paper on the "Buried Valley of the Mersey," before referred to.

clay of the neighbourhood. In other instances yellow sand occurs sometimes, as at the Hooton Well, of considerable thickness, and interstratified with gravel. In portions of the dock excavations good examples of current-bedded sands and gravels of limited thickness were observed and sketched by me at the time. Occasionally the red sand from below occurs in veins included in the clay itself, but always near the base. One of the advantages of watching excavations over an extended area is, that parallel sections can be obtained showing the variations in the beds laterally, from which we may form a good notion of the horizontal boundaries of the deposits. Single vertical sections, such as are exposed in a railway cutting, are often misleading. In one of the sections referred to, recorded in my note-book, the ground moraine of red sand and rubble fills up saw-like notches in the rock below, the serrations probably arising from the crushing of the upturned edges of the beds, which, as before stated, dip at an angle of 18°. Above this is a layer of the red sand; then current-bedded yellow sand and gravel; and above that, clay and gravel mixed. In another section a bed of "book leaf" clay from half-an-inch to one inch thick, thinning out to nothing in each direction, occurs in the clay near the base; and, above that again, with a couple of feet of unlaminated clay between, is a mass of Boulder-clay in laminations about two inches thick and when dry, splitting up into flaggy fragments, the whole being studded with the usual erratics. While in some cases the clay appeared to be quite unstratified, in others divisional planes were very perceptible. Decomposed granite and greenstone boulders were of frequent occurrence and, in one spot especially thick with them, looked like almonds in a pudding, being cut in twain by the navvies' pick, and showing as sections

in the clayey mass. Divisional planes are characteristic of the Boulder-clay of the neighbourhood, and are to be seen in the cliffs above Garston; but the most remarkable instance of persistence in a bed of this kind was one disclosed in the railway cutting at Farnworth, where a bed of sand and gravel not more than from three inches to six inches thick divides the deposit in two, sweeping over in a curve approximately concentric with the rock below for a distance of five-eighths of a mile. Extensive included beds of laminated sand and gravel showed in the cutting west of Hunts Cross Station, and very curious instances of cross laminations and curved laminated beds occurred nearer to Garston. Weathering brings out these laminations very distinctly, forming connecting stalactitic drops of clay between. There are also pot-holes of sand, and barren unlaminated beds of sand containing neither shells nor stones.

The nature of the clay itself varies within certain limits, the bottom and oldest beds being generally the hardest and most compact, and, as a rule, containing the most stones. In the Widnes borings, as I have before described, the clay, especially towards the bottom, is of a fine unctuous character, like some of the beds at Bootle Lane Station.

Shell Fragments.—Included in the clay generally, and sometimes in laminated seams of sand, are shell fragments proving the whole to be a Marine Deposit. I found representatives of the following species:—*Mya truncata, L., Tellina balthica, L., Venus gallina, L., Astarte borealis Chem, Cardium Edule, L., Littorina litorea, L., Turritella terebra, L., Purpura lapillus, L., Buccinum undatum, L.* As I have elsewhere* developed this portion of my subject, I will not repeat it here.

* "The Drift Beds of the North-West of England."—*Quarterly Journal of the Geological Society*, 1874, p. 281.

Proportion in which Erratic Fragments occur.—I have not at Garston estimated the proportion in which the various formations are represented; but at Great Crosby in a similar deposit, I carefully estimated them; they were as follows:—

1. Granites, Syenites, and Porphyries...	23
2. Greenstones, Felstones, and Tuffs, many being Porphyritic	31
3. Old Red Sandstone.....	1
4. Cambrian and Silurian Grits and Slates, &c.	28
5. Carboniferous Limestones.....	8
6. ,, Sandstones	8
7. Triassic Sandstones and Marls	1
	100

I also found, in one instance, the proportion of stones to the mass of clay to be one in 1200, while in another instance it rose as high as one in 130. Probably the average would be about one in 900. These proportions were estimated by measuring the excavations and the heap of stones taken out, and, of course, are only approximate.

Striated Stones.—If the molluscous fauna of the Boulder-clay does not indicate the intense conditions of cold one would expect, there are indisputable records of severe ice action in the planed and striated boulders, pebbles, and blocks profusely embedded in the whole series of deposits. The proportion of striated stones among those mentioned was as follows:—

No. 1.....None were properly striated, being mostly rounded and subangular.
,, 2.....13 were striated.
,, 4.....26 ,,
,, 5..... 8 ,,
,, 6.....None were distinctly striated.

Thus, out of 100 stones 47, or nearly half, bore marks of ice action. I consider this excellent evidence of the existence of Glaciers at the time the Marine Boulder-clays were being deposited.

Parent Rocks.—It will be observed that 83 per cent. are of such rocks as can only be derived from the Cumbrian or Welsh mountains; and, after much trouble and care, I have succeeded in identifying—in addition to the Eskdale Granite first discovered in the Drift by Mr. Mackintosh—the Syenite of Buttermere, which also occurs plentifully scattered over the Macclesfield Hills in the form of large blocks. Is not this presumptive evidence of the former existence of Glaciers in the mountains from which most of these rocks were torn, especially if taken together with the ice markings so sharply cut in them, and freshly preserved to the present day?

Evidences of Tidal Action.—From an extensive series of observations, I am of opinion that none of the deposits described are of littoral origin, excepting in so far as they have been swept from the shores to the deeps; and that the current-bedded sands and gravels, the laminated sands, the divisional planes, the finely laminated beds of clay, were all formed below low water by Tidal Action, and often at considerable depths. I have shown that the tide-wave acts at the bottom of the sea even at the greatest depths,* and that it is capable, in many instances, of considerable erosive action. The almost universal prevalence of shell fragments, of only a small size, also leads to the belief that they have been sorted by the tidal current, as I find that dredgings in the silts of the estuary of the Mersey show a preponderance of small shell fragments.

* "Tidal Action as a Geological Cause."—*Proc. of Liverpool Geo. Soc.*, 1873-4.

Post-Glacial Beds.—These deposits occurred in a gulley cut in the Boulder-clay, and in level lay between high and low water. The sequence of beds was well borne out in the several sections across the whole width of the dock, and confirmed my determination of them in the section before referred to in my "Post-Glacial Geology of Lancashire and Cheshire." They are instructive, as showing conclusively a Post-glacial downward movement of the land by physical evidence altogether apart from inferences drawn from the submerged forests.

The deposits lay invariably in the north side of the gulley, the opposite side being apparently denuded by the inrush of the tide up the Mersey; and they widened out as they approached low-water mark, as also did the gulley itself. A reference to the original section will show that Deposit No. 3, coarse flesh-coloured sand, and No. 4, yellow sand, are coloured as equivalents of the Washed-Drift sand; but further down laminated silt occurred, leading me to suppose that the upper beds were re-arranged and contemporaneous with the Formby and Leasowe Marine Beds. Peat Bed No. 5, I found, occurred with stools of trees in situ in a patch on the floor of the gulley, resting upon a thin bed of silty sand. Bed No. 6, undoubtedly recent, contained *Scrobicularia piperata* in situ, and showed an interesting example of cross laminations arranged at all angles with partings of comminuted peat. This, as occurring in *mud*, was instructive; and, no doubt, due to the eddying tidal currents created by the gulley.

In conclusion, I may point out that it is not often we can get a complete series of deposits, such as these, contained in one section, exhibiting beds from the commencement of the Glacial Period down to the present time; and, in addition, so disposed as to throw consider-

able light on several physical questions of successive subsidences and re-elevations, which I have on other occasions called your attention to. Within the limits of this short paper it has been impossible for me to do much more than describe facts, but they are such as I believe to be fully worth recording, and therefore, it has been with much pleasure I have laid them before you. The very means through which such information is obtained involves the destruction of the record itself. I wish that this reflection would induce those who have the opportunity not to omit to record, or to let others profit by observations of a similar nature.

JANUARY, 12TH, 1875.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

CONYERS KIRBY, C.E., and BRICE M. WRIGHT, F.R.Hist.S., were elected Ordinary Members.

The following communication was read:—

THE CARBONIFEROUS LIMESTONE AND MILLSTONE GRIT OF THE COUNTRY SOUTH OF LLANGOLLEN.

BY GEORGE H. MORTON, F.G.S.

The publication of this paper is unavoidably postponed until next year.

FEBRUARY 9TH, 1875.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following communications were read:—

THE METALLIC ORES OF CORNWALL—GROUP 1: TIN, COPPER, IRON, AND LEAD.

By William Semmons, F.G.S.

Perhaps no district in the United Kingdom of similar extent has yielded so many combinations of the various metals as the mining district of Cornwall. Of some metals it furnishes our total British supply, while of almost all of them it appears to furnish marketable quantities.

Tin.—First in importance stands the ores or rather ore of Tin, the value of which as an object of industry may be estimated by the fact that in 1873 no less than 14,885 tons "Black" Tin were sold from Devon and Cornwall, producing £1,056,835. The production in Devon is but a small part of this quantity, and from these two counties all our British Tin is obtained. The Tin mines are scattered over the whole of Cornwall. but are chiefly confined to the Granite ridge, which traverses it from N.E. to S.W.; and a very large proportion of the yield is extracted from an area which might be comprised in a circle having a radius of 1½ mile. From two sets of veins, the one running along the north and the other along the south side of Carn Bré Range, about one third of the present production is obtained. Carn Bré forms the northern limit of a large exposure of Granite, the whole of which is probably stanniferous; and along its flanks rests the clay slate or killas, which covers so large a portion of the low lands of the county.

Cassiterite, Sn. O_2, the ore which furnishes the exclusive supply of this metal, is usually found associated with Chlorite, Quartz, and other minerals. Although this mineral crystallises in the Pyramidal system, which

admits of but few variations compared with some of the other systems, one conversant with the locality can generally pronounce with certainty the district from which a specimen has been raised, so exquisitely poised are the forces which regulate the deposition of these crystals. The average produce of the Tinstuff raised is probably less than 5 per cent.; and the extraction of the ore from its matrix, in consequence, becomes a matter of prime importance to the miner. This is principally effected by washing, advantage being taken of the high specific gravity of the mineral. Roasting has to be resorted to, in order to get rid of the Arsenic in Mispickel, which is a frequent companion of Cassiterite. Wolfram, with which it is sometimes associated, requires a more complicated process for its extraction.

Stannine, a mineral now usually considered a Sulphostannate of Copper and Iron, is found mixed with other ores, generally those of Copper.

Copper.—The number of combinations which Copper enters into with other elements is very great, and a very large proportion of these is found in Cornwall. Perhaps no less than 30 Copper ores of well-defined composition are met with in addition to several others, which help to fill the cabinets of mineralogists.

In a native state, it is found in the Granite, Clay Slate, and Serpentine Rock.

Combined with Oxygen we have—

Cuprite ..... Cu_2O

Melaconite ..... CuO

Cuprite has been found occasionally in large quantities. It is often crystallised, even when it occurs in masses. The capillary variety Chalcotrichite is rare.

In Carbonates—

Azurite..... $2\,CuCO_3,\ CuH_2O_2$

Malachite..... $CuCO_3,\ CuH_2O_2$

The Cornish Malachite is not so compact as the Australian and Russian varieties, and consequently is but little used for ornamental purposes. Specimens are sometimes met with showing crystals of Cuprite partially converted into Malachite, similar to those met with at Chessy.

Chrysocolla a silicate, $Cu\ Si\ O_3 + 2\ H_2\ O$, found also in small quantities, appears to be a product of decomposition of other Copper ores.

Condurrite, $Cu_3\ As$, a rare mineral is, I believe, the only combination with Arsenic found here.

The Sulphides are represented by—

Redruthite.....	$Cu_2\ S$
Covellite	$Cu\ S$
Bornite	$3\ Cu_2\ S\ ,\ Fe_2\ S_3$
Towanite	$Cu_2\ S\ ,\ Fe_2\ S_3$

Redruthite has been found in large quantities; and some of the crystals, particularly the Nail-headed variety, are remarkable for their size and brilliancy.

Bornite is a very common ore. A noticeable fact about this mineral is, that crystals of it are confined to so few localities.

Covellite is only found in small quantities.

Towanite, which is in Cornwall as in most places the principal ore of Copper, is found in almost every mine where Copper has been extracted.

A most interesting group of minerals, showing the interchangeability of Sulphur, Arsenic, and Antimony, is composed of Fahlerz, Bournonite, Tennantite, and Polybasite.

The Cornish crystals of Bournonite are perhaps the finest that have been raised, whilst those of Fahlerz, with their almost invariable covering of Towanite, are interesting from showing pauses in the act of deposition, aad a change in the character of the deposit. Atacamite

represents the oxychlorides of Copper. Those compounds which represent the decomposition of other ores are well represented—In the Sulphates we have Cyanosite, Langite, and Brochantite, which represent various stages of hydration; while no less than ten minerals are found in the group of Arseniates and Phosphates.

Lead.—The ores of Lead are comparatively few; those of commercial importance are very few. They are well represented in Cornwall.

Plumbic Ochre, a rare mineral here, represents the oxides.

The Carbonate, Pb CO_3, Cerussite, is frequently met with here, though not in large quantities. Some crystals of great size and beauty have been found in one or two localities.

The principal source of Lead here, as in most localities, is Galena, Pb S. This mineral is found in veins, of which it is the sole or main constitutent, and also associated with ores of Tin, Copper, and Iron.

A rare combination Chloride and Carbonate is illustrated by the mineral Cromfordite Pb CO_3, Pb Cl_2, of which a few specimens have been found.

Several minerals, of which Pyromorphite and Mimetite are the most common, represent the Phosphates and Arseniates.

We may note here the frequent occurrence of Plumbic Chloride, in combination, in the ores of Lead; although, distinct, it has, I believe, only been found two or three times.

The Sulphate Anglesite is a rare mineral here, as is also the Cupreous Sulphate, Linarite; while the Antimonates are represented by Bleinerite.

The percentage of Silver in the Cornish lead ores is much greater than the average of the United Kingdom.

Cornish lead ores average 40 ounces per ton, while the average of the whole of the British mines is slightly under 10 ounces per ton.

Iron.—The value of the Iron ores raised in the county is at present but small; not, however, through lack of quantity, but from lack of development.

Magnetite $Fe_3 O_4$ is only found in small quantities.

Hematite $Fe_2 O_3$ is present in almost every mineral vein, and associated with the ores of other metals.

Goethite, $Fe_2 O_3, H_2 O$, is found in several mines. The Restormel mines have yielded some remarkable specimens.

Limonite, $2 Fe_2 O_3, 3 H_2 O$ is found in great abundance. Gossan, an ochreous deposit seen on the out-crop of the Cornish veins, is largely composed of this mineral.

Chalybite, $Fe C O_3$, is found in many places. Some of these rhombohedral crystals have their extemities so truncated as to resemble octohedrons of the cubic system, and are therefore of great interest.

The Sulphur compounds are well represented.

Pyrrhotine, $Fe_7 S_8$, the magnetic variety, is found but rarely.

The Ferric dissulphide is found in both its dimorphic forms, Pyrite and Marcasite.

Pyrite occurs in crystals presenting every modification of the cubic system, and is very abundant.

Marcasite, in its varied forms, is also a common mineral. The occurence of these minerals immediately superimposed on each other lends some support to the theory of deposition from solution, a change in conditions causing a change in form.

Mispickel, Fe As S, is found abundantly; and, from its high specific gravity is one of the impurities which cannot be extracted from Cassiterite by washing. The

roasting of this mineral, and the consequent formation of Arsenious anhydride, constitutes a considerable source of income to some mines.

Lencopyrite, Fe As_2, found in small quantities only, shows the complete replacement of Sulphur by Arsenic.

The Arseniates and Phosphates are comparatively rare, but are represented by Vivianite, Pharmacosiderite, Scorodite, and Pitticite.

The Silicates are represented by those rare minerals Chloropal and Cronstedite, while Melanterite represents the Sulphates.

Wolfram, Fe WO_4, frequently occurs mixed with Tin ore.

During the past few years the workings on the Iron lodes in Cornwall have assumed quite another aspect to their former appearance. Large sums of money have been spent on their development, and it seems certain that in the course of a short time this branch of metallic mining will be one of great importance. One of these lodes, known as the Perran Iron lode, is in some places no less than 100 feet wide; consisting at the surface of Brown oxide of Iron, passing as we descend into Chalybite. The Chalybite is remarkably free from Phosphorus and Sulphur, and is of the description required for the manufacture of Bessemer Steel. In some places they have sunk through the Chalybite, and there find the lode to contain Blende, Galena, and Towanite. This deposit of Iron, therefore, appears to be a gigantic Gossan on the back of a Copper or Lead lode, and most miners think the amount of mineral beneath will be very great.

The foregoing minerals are obtained from two sources:—Stream works and Vein mining.

The Stream works are confined to alluvial deposits, in which Cassiterite is found, and occasionally other

heavy minerals; as for instance, though but rarely, Gold. This method of obtaining minerals would naturally occur in the first instance to a rude people; but, as this source would be soon exhausted, they would be driven to work on the veins from which the alluvial deposits were derived.

Vein mining is therefore of ancient date, particularly for Tin. Most authorities are now agreed that the Ictis of Diodorus, from whence the Tin was shipped by the Phœnicians, was one of the islands on the Cornish coast.

Copper mining appears to have been developed at a more recent date, for we read of Sir Walter Raleigh reporting to Queen Elizabeth that the Copper ores of Cornwall were of little value.

The Cornish veins may be divided into two classes:—

1.—E. and W. veins—containing Tin, Copper, Iron Gossan, and but little Lead.

2.—N. and S. veins—frequently comprised of Clay, containing sometimes Lead ore and Iron.

The contra veins are intermediate in their direction. For a description of these veins I would refer to—W. J. Henwood's great work, also to papers by Carne—*Trans. Royal Geol. Soc.*, Cornwall.

The direction of a vein appears in many cases to affect its productiveness. Charles Thomas, a man of great practical experience, in his little work gives an instance where the relation between them is well shown viz.,—in the lode at Alfred Consols Mine.

The "dip" of lodes is extremely variable, and the same lode is generally more inclined in some places than in others. Not only is this the case, but, frequently on a shaft being sunk, the lode is found to dip on both sides of the perpendicular in the course of 100 fathoms. This variation in the direction and dip of lodes gives rise to

numberless intersections, the result of which appears more to increase than diminish their productiveness, though instances could be given of both effects.

A peculiar fact with regard to N. and S. lodes containing Lead is that, when they are crossed by E. and W. lodes, the Lead ore becomes richer for Silver. At Wheal Ludcott the Lead lodes at these intersections produced native Silver and Silver ores. The great Perran Iron lode intersects several Lead veins. In one place at Treskerby Green the Galena yielded over 3,000 ounces of Silver per ton; in another, Wheal Peru, a large mass of native Silver was found.

This fact, taken in connection with Robert Were Fox's researches on the electrical condition of veins, tends much to support the theory of deposition from solution. The numerous cases of pseudomorphism show that chemical change is ever at work; while endomorphs give undoubted evidence of lapse of time and change of conditions during the filling up of the veins.

The following are the writers who have described the district:—De la Beche, F.R.S., R. Were Fox, F.R.S., W. W. Smyth, F.R.S., W. J. Henwood, F.R.S., J. Garby, R. Pearce, F.G.S., J. H. Collins, F.G.S., and others. Mr. Collins' work is an invaluable guide.

SPECULATIONS ON THE PROBABLE DISTRIBUTION OF LAND AND SEA DURING THE DEPOSITION OF THE MARINE BOULDER-CLAYS AND SANDS.

By T. Mellard Reade, C.E., F.G.S.

It is, I believe, to Lyell the credit is due of first conceiving and clearly stating the changes of climate that may result from a given distribution of land and

sea. Since he gave his views to the world there has, however, been an increasing tendency to attribute the cold of the Glacial Period to astronomical rather than to geographical causes. While not disposed to undervalue the effect which a change in the eccentricity of the earth's orbit might produce, or of a change in the inclination of the earth's axis to the ecliptic—of which, however, astronomers say they have no evidence—it may be as well if we revert to the effect of known causes, and keep clearly in view what agencies now at work are capable of effecting.

Assuming that the axis of the earth was practically at its present angle to the ecliptic in the comparatively recent period of the Marine Boulder-clays of the N.W. of England, it follows that an extension of cold into lower latitudes would not create the same climatic conditions as a similar mean degree of annual temperature in higher latitudes. If the extension of cold towards the Equator only affected one portion in longitude of the circumference of the globe, the summer Isotherms would vary less in latitude than the winter Isotherms; while, if the Glacial conditions were equally distributed, the summer and winter Isotherms might be nearly parallel in direction. On the other hand, it is quite evident, from the altitude of the sun in summer, the heat might then be great, though the winter temperature were exceedingly low.* Through speculations of this kind, it has occurred to me, that the puzzling mixture of a few southern or Lusitanean, with the prevailing northern forms of the testaceous fauna of the Boulder-clay, may be due to these variations of the seasons. Such conditions would, I think, be likely to produce currents of varying

* A reference to the Isothermal lines of the globe will show how they are affected in this manner now.

temperature, and the proximity of such currents to each other would have the effect of bringing the Southern and northern forms into close proximity.

As regards the degree of cold indicated by the fauna of the Boulder-clay, we have only to turn our attention to the present condition of the North American Continent to see that present causes are quite competent to produce sea conditions fitted for such an assemblage of molluscs.

It is true that there are now no Glaciers in North America in this latitude, but, if the land were more mountainous and the prevailing wind blew from the east instead of the west, it is quite possible that the hygrometrical conditions would be such as to create a great fall of snow such as we know takes place at Tierra del Fuego, lying on the southern parallel corresponding to the northern one on which the deposits in question lie; and, therefore, Glacial conditions may have prevailed without the sea being necessarily of a very low temperature.

Lyell and Forbes have pointed out that there must have been a littoral or shore connection between the Continent of America and Europe in Post-tertiary times to account for the similarity of the testaceous fauna on both sides of the Atlantic. It does not follow, however, that this connection was at any one time *continuous;* a very slow wave of upheaval of the land would be sufficient to carry the fauna from one continent to the other. It is thus presumable that there was, during the Glacial Period, a preponderance of land towards the North Pole, and these successive and wave-like subsidences and upheavals are probably connected with the Icelandic Volcanic system.

The oscillations of level of the land, which are proved

to have taken place during the Glacial Period, increasing northwards from a zero line from London to Bristol to 2,000 feet in Wales, and possibly more in Scotland, show that the disturbing causes—deep-seated, no doubt—must have been situated in the far north. It is also not improbable that a depression of 2,000 feet may have been preceded by a rise to a similar or greater extent; and this in itself would be sufficient to intensify, if not to produce, Glacial conditions.

Thus, if we find an alteration in the distribution of land and water—such as we have good reasons for supposing actually took place—competent to produce the effects we see in the Marine Drift, it seems unnecessary for our purpose to invoke, in addition, the aid of astronomical causes. And, further, if the cold at this period was not due to other than geographical causes, it is quite evident that though the isothermal lines would at that time trend further south in Europe than they do now, the summers might be very hot, and the winters very cold.*

This is exactly what takes place, perhaps in a lesser degree, in the same latitudes in North America; and we find, according to Forbes and others, that the Arctic and the American representatives of the Lusitanean Province meet and actually intermingle at Cape Cod in lat. 42°. Southern shells are there dredged up with Arctic species.

It is not, then, a very violent supposition to ascribe, as I have suggested, the presence of southern forms, such as *Venus chione, Cardium rusticum, C. aculeatum,*

*A reference to the concluding paragraphs will show that, the opposite of this takes place in Tierra del Fuego—that the summer temperature is there very low. This is a local condition, but one eminently fitted to produce glaciers, when combined with the high temperature of the inflowing waters heated in adjoining seas.

and *Arca lactea* found in the Lancashire Drift, along with a great preponderance of Arctic forms to the extremes of cold and heat, peculiar to a low latitude under Glacial conditions.

It may, perhaps, be urged that in the case of the Boulder-clay this is invoking too great a machinery to account for the presence of only *one* southern shell, viz :—*Venus chione*. There are, however, other circumstances to be considered. We know that some forms are far more persistent than others, and adapt themselves to changed conditions more readily. We also know that several shells common to the crag have since retired into Arctic or northern seas.* If, therefore, shells ranging further south, when warmer conditions prevailed, have since retired north, there is no violence in supposing that a southern shell retired further south, even after living through the Glacial seas in these localities. The apparent anomaly remains to be accounted for in some way, and, as the course of the erratic boulders contained in the clay shows that the Drift-ice was from the *north*, the shells could hardly be travelled ones from the south, unless brought up by tidal action, of which there is an absence of evidence. The frequency of the occurrence of *Venus chione*, at Macclesfield and Edge Hill, is also strongly confirmatory of its being a local shell.†

The beds in our neighbourhood lie midway between the 53rd and 54th parallels of latitude; and, though now a comparatively mild and equable climate prevails, Liverpool is as far north as a considerable portion of the

* *Astarte borealis* among the number.

† The presence of Lusitanean Forms is not peculiar to the Drift of Lancashire, *Cardium aculeatum* and *C. pygmæum* occurring in the Scotch clays. See A. Geikie "On the Phenomena of the Glacial Drift."—*Tran. of Glasgow Geol. Society.*

ungenial coast of Labrador, the extreme northern point of which is on the same parallel as the Shetland Isles. If we contrast the climates of the two places, we shall have less difficulty in understanding how readily a change in the distribution of land and sea, and consequently marine currents, might re-introduce a condition of things indicated by the Drift-beds of Lancashire. We have seen that the Arctic and southern faunas on the opposite side of the Atlantic meet, and actually intermingle at Cape Cod in latitude 42°, or over 11 degrees further south than Liverpool, and that these two places are about on the same Isothermal line of mean summer temperature. Doubtless, this meeting of the southern and Boreal fauna is due to the impinging of the cold currents of the north upon the warmer ones from the Gulf of Mexico; and the sharp line of division also probably results from the same physical causes, combined with the separation of the two streams by this Cape. It is instructive, as bearing upon the question before us, to notice the wedge-like thinning out of the southern and Boreal areas on the east coast of America in this latitude; and will help, as before pointed out, to explain the otherwise anomalous appearance of southern forms in the Drift that now do not range so far north.*

During the Glacial Period, so far as we know, no more northern forms than *Cyprina Islandica, Mya truncata, Panopea Norvegica,* and *Buccinum undatum,* which are found in the Cicilian beds, reached to the Mediterranean, or 4 degrees further south than Cape Cod. There is, however, in the Glacial beds, so far as at present known, no sharp line of division showing a northern

* Forbes notes the discovery by Captain James of *Turritella incrassata,* a crag fossil, a southern form of *fusus,* and a *mitra* allied to the Spanish species, in the Wexford gravels.

assemblage of shells in contiguity with those of a southern type, such as would be exhibited to us were the land about Cape Cod elevated and the beds exposed. Though we find a sprinkling of southern shells in the Glacial beds, the general evidences are that the conditions of the sea favourable to the northern species were more diffused, wide-spread, and embraced a larger area than what we see in America. In estimating the relative intensity of cold prevailing now in North America, as compared with the former cold of Europe, we must also not lose sight of the configuration of the land, and the changes it would produce in the currents from the north or south. Thus, though the Mediterranean during the Glacial Period were connected with the Atlantic on the one hand and the Red Sea on the other, it would be out of the line of the great northern currents, consequently an intense cold would be unlikely to prevail.

In the more northerly parts of America we find that the climate of the more sterile regions of the Hudson's Bay territory is much colder even than Greenland under the same latitude. At Winter Island, 66° 11" N. lat., 83° 30" W. long., the mean annual temperature does not exceed 7° Fahrenheit, the maximum of heat observed being 54° and the minimum—42°. At Fort Franklin, about 230 feet above the sea, and only one degree further south, viz., 65° 12" N. lat., but in longitude 132° 13" W. and situated in the Mackenzie Valley, the mean annual temperature is 17°, the maximum of heat is 80°, and the minimum—58°. The mean annual temperature at Fort Chippewa, on the banks of Lake Athabasca, 58° 43" N. lat., does not rise above freezing point, or 30°.*

It is thus seen that proximity to the Arctic currents, through Baffin's Bay and the archipelago of islands

* English Cyclopædia—Article, "Hudson's Bay Territory."

dividing North America from Greenland, makes a difference of 10° mean annual temperature between Winter Island and Fort Franklin; which, being 48° 43" to the westward, is subject to the ameliorating influences of the Pacific Ocean and the eastward extension of the Japanese current. On the other hand, to the eastward the mean annual temperature of Greenland, to some extent open to the influences of the North Atlantic, is much higher. The American pole of *relative* cold* is in lat. 65° N., long. 96° W., near Wager Inlet, at the north-east coast of Hudson's Bay, where the mean deficit of annual temperature over a normal climate due to the same latitude is—13°. The American pole of *actual* cold is situated about 11° further north on the same meridian. Quebec is affected with a mean deficit of 6½°, and New York by 4°. When we consider that the line of permanent ground frost includes most of Labrador, we can form some conception of the influence of cold currents. Turning our attention to the continent of Asia by way of contrast, it is instructive to find intense cold produced by a different set of causes; for at Yakutsk, the Siberian focus of relative cold, there is a mean annual deficiency of—15°, referable to the extension across Asia of lofty mountain chains between the 30th and 40th parallels, which increase the rigour of the winter to the countries north of them by intercepting the south-west anti-trade, and obliging it to deposit its moisture on their summits; thus draining it of its latent heat, which would otherwise be given out to the plains beyond in rain or snow.† In

* The pole of relative cold is that focus where the temperature falls the most below what would be due to the latitude in which it is situated, on the supposition of a normal climate. The pole of actual cold is the focus of the absolutely greatest cold.

† The soil at Yakutsk is frozen to a depth of 630 feet—Sir J. Herschell's "Physical Geography," p. 235.

one case the distributor of temperature is the *sea* and atmosphere, in the other *solely* the atmosphere. Is it not, then, quite evident from these facts that the distribution of land and sea, their physical configuration, together with the direction of currents either of water or air, are competent to produce the conditions of cold shown in the marine drift-beds of Britain?

Marine Evidences of intense Cold on the East Coast of Britain.—It is a remarkable fact that the east coast of Britain presents us with a much more northern fauna as characteristic of the earlier drift-beds than those of the west.

At Elie, in Fifeshire, and Errol, in Perthshire, the Rev. Thos. Brown found shells pronounced by Dr. Otto Torrel to be the exact representatives of those now living in front of the great Glacier of Spitzbergen.* The Bridlington beds on the coast of Yorkshire are also shown by Mr. Searles Wood, junr., to indicate more arctic conditions than any of those found either in Lancashire or in the Clyde laminated clays. Mr. Wood also offers very good evidence in favour of the greater age of these east coast beds;† in which opinion, from a variety of considerations, and not trusting entirely to the *facies* of the several assemblages, I am inclined to concur. If this be so, it is then quite evident to me, after closely inspecting the base of the clay beds at every available point in this district, that the *conditions on the west coast were subaërial at the time those on the east were submarine.* If this were so, the amelioration of the climate set in before the Lancashire plains were sub-

* Tran. of the Royal Soc. of Edin., vol. 24, p. 627.

† "Quarterly Journal of Geological Society," 1869, p. 97.

merged,* and it would be quite conceivable that if the German Ocean were flanked by a considerable extension of land to the westward, and also to the eastward, under glacial conditions, the then channel would be under somewhat similar physical conditions to that portion of the Hudson's Bay territory near to Winter Island.

The absence of Tertiary beds on the west coast lends further probability to this supposition. The red and coralline crags occurring only on the south-east angle of England—unless equivalent deposits have been denuded from the west coast, of which I am not aware there is any evidence—show that seas existed then on the site of the German Ocean. It is considered by Lyell† and Prestwich, that even during these periods floating ice must have existed from the "presence of huge irregular, quite unrounded chalk flints, retaining their white coating, and 2 feet by 1 foot 6 inches, in beds, worked for phosphatic nodules at Foxhall, four miles south-east of Ipswich;" and the occurrence of a large block of Porphyry at Sutton in the base of the coralline crag. We thus have evidence of a succession of marine deposits on the east coast, dating from the coralline crag, which are absent on the west coast. If we combine this fact with presence of Arctic species in the Drift on the east that are not found on the west coast, underlying a Drift —such as that of Caithness, described by Mr. Jamieson, and seemingly precisely similar to our low-level Boulder-clay—it is difficult to resist the conclusion that there was an extension of land to the westward during the more severe part of the Glacial Period.

* The more I extend my inspection of the base of the Boulder-clay in the north-west of England, the more clearly it appears to me that there is a great break in *time* between the period of the rock groovings and that of the marine clays.

† Lyell's "Students Elements of Geology," pp. 176-7.

When we find a difference of relative level occurred during the later stages of the Glacial Period, between the Bristol Channel and Snowdon, of 2,000 feet, forming a gradient of 1 in 330—a wave of elevation, in fact—it is readily conceivable that such difference of relative level, or flexure of the earth's crust, may have, propagated itself also westward and eastward; and an elevation of 600 feet at the 100-fathom line on the west coast of Ireland, shading off into nothing as it approached the east coast of England, giving a gradient of about 1 in 4,400, would, during the prevalence of cold and the existence of land to the northward, now submerged, together with a simultaneous submergence of the northern part of Africa, which we know happened in Post-pliocene times,* produce the conditions that prevailed at the time the Bridlington and other extreme Glacial-beds of the east coast were laid down.† Until I deal comprehensively with the stratigraphical portion of my investigations, it will, however, be impossible to correlate the Lancashire beds precisely with those so carefully and elaborately worked out by Mr. Searles Wood, junr. The great submergence, culminating in 2,000 feet in Wales and Scotland, must have had considerable local climatic effect; and would, one is inclined to suppose, of itself, independently of what was taking place elsewhere, tend to raise and equalize the temperature. It is, however, clear that the Moel Tryfaen shell list shows a rather more northern *facies* than that of the Lancashire clays, and still more than that of the

* See Mr. Maw's Paper. "Notes on a Journey from Algiers to the Sahara."—*Quart. Journ. Geol. Soc.*, vol. xxx, page 121.

† To enable us to draw a map of the relative amount and distribution of land and sea, it would be necessary to ascertain the synchronisms of the submergences. From what I suppose to have been the wave-like characters of the earth movements, this synchronism would be a very difficult problem to work out.

Macclesfield cemetery beds. There is, however, nothing at Moel Tryfaen in the constitution of the beds themselves to suggest any greater severity of climate; and I am inclined to think that the difference arises mainly from the spot being in proximity to the mountain district generating the glaciers, though at that time Snowdonia would form an assemblage of small islands.

Having now pointed out the competency of Geographical causes to produce the later stages of the Glacial conditions, and the probability that such a distribution of land and sea did prevail, I may at the same time express my opinion that there appears to have been in the northern hemisphere such an uniform extension of cold southwards round the circumference of the globe, as to lead to the belief that at an earlier period a general or cosmical cause co-operated with the agencies I have mentioned; and it is quite probable that the astronomical effects graduated into geographical effects. It is also evident to me that the intensest period of cold cannot be paralleled by anything we see now; therefore, I am not inclined to ascribe the Glacial Period solely to geographical causes, but rather to astronomical, *re-inforced* by suitable geographical conditions.

The archipelago of Tierra del Fuego, lying between 52° 30" and 56° S. latitude, has an extremely cold climate. Cloudy weather, rain, and wind prevail throughout the year, and fine days are rare. In the mountainous part of King Charles' Southland, the largest of the islands, Glaciers descend into the sea from almost every valley. Notwithstanding this, the surface of the sea in the Straits of Magalhaens is never lower than 45° Fahrenheit; though the coasts exposed to the influence of the open ocean probably possess a colder climate, as they are in the winter surrounded by large fields of ice. The mean

winter temperature is 2½° above freezing point, though it occasionally descends to 12½° of Fahrenheit. The snow line is often 3500 to 4000 feet. The existence of Glaciers is probably largely due in this case to the low mean summer temperature and the warm current of water to the inflow from the west coast of South America. The prevailing winds are westerly, and those traversing the Antarctic current will be reduced in temperature. No season is, in fact, quite free from frost; even in February, corresponding with our August, the thermometer descends occasionally a few degrees below freezing point. The climate is altogether peculiar, as fogs are extremely rare; but thick rainy weather prevails, and strong winds. The sun shows itself but little, the sky, even in fine weather being generally overcast and cloudy. A clear day is a very rare occurrence.

The prevalence of winds seem to point to variations of temperature, probably produced by the mingling of air of different temperatures from the north and south, and this would also account for the precipitation of rain and snow. That the atmosphere is drained of its moisture is shown by the level portion of King Charles' Southland, to the eastward of the mountainous district, suffering from want of moisture.

It follows from this example that an extension of cold into lower latitudes is favourable to the creation of currents of water of a temperature different to that of the atmosphere at the same place; for though in this case the summer days are seldom very hot, from the sky being continually overcast, the water heated in adjoining seas flows in to restore the balance of temperature. A warm current would also supply the evaporating surface for the production of moisture, and hence snow. The colder air would get super-saturated; and, expanding as it

rose into a higher stratum, when ascending the mountain range, would re-deposit its moisture either as rain or snow. A low mean summer temperature would also be favourable to glacial conditions. The presence of southern forms in the Boulder-clay would rather lead us to think that geographical causes were then more potent than astronomical; at the same time, we have also at Tierra del Fuego indications from old moraines of a former extension of Glaciers. It is the cumulative evidence, both in the south and north, at almost every locality that has been examined, of a former extension of cold towards the Equator, that leads irresistibly to the belief that it was in its intensest form due to cosmical causes. It seems hardly probable that the changes of land and sea could have so uniformly affected the globe this way, even if we consider the existence of the cold as successive, and not synchronous. There is, in fact, no point now on the earth's surface in which we have conditions of cold as intense in the same parallel as during the Glacial Period.

North America.—As showing that the Glacial period was really a "period," and not the mere localisation of cold in Europe, I may point to the extension of Glacial deposits to the 42nd parallel in North America. Lyell describes a train of erratic blocks, rounded on the top, which occurs in the State of New York, thus showing that the cold affected that continent *proportionably;* for no similar example occurs in Europe in so low a latitude, though there is evidence that the southern range of the Reindeer extended to the south of France and the Lake of Geneva, and may have extended further. The southern limit of the Reindeer in North America now is the 50th parallel, or about the same distance south as the Land's End.

MARCH 9TH, 1875.

THE VICE-PRESIDENT, R. A. ESKRIGGE, F.G.S., in the Chair.

Dr. JAMES CAMPBELL BROWN, F.G.S., was elected an Ordinary Member.

The following communication was read:—

THE CAUSE OF THE GLACIAL PERIOD WITH REFERENCE TO GREAT BRITAIN.

BY CHARLES RICKETTS, M.D., F.G.S.

SOME who consider that the Glacial Period was dependent on extreme cold, caused by the winters occurring when the earth was in aphelion, with a greatly increased eccentricity of its orbit, have deduced inferences which do not appear to accord with present physical conditions.

With great glacier systems, such as existed in North America and in Europe, the air would have had almost the whole of its moisture condensed out of it by the cold long before it reached the Arctic Circle; consequently glaciers could not then have existed on the water slope of the land surrounding the Arctic Ocean, any more than they do now; and, so far from there being an "ice-cap" covering the Arctic regions, there would not have been sufficient moisture left to form in it ice-floes so great or extensive as at present.

The increased accumulation of snow now taking place in Greenland is accompanied by subsidence of the land, whilst elevation is at the same time rapidly occurring in Norway and Spitzbergen; it is, therefore, not requisite

to attribute "the invariable occurrence of submergence along with glaciation, to change in the centre of gravity of the earth." The cause of the present subsidence in Great Britain during the Glacial Period was ascribed to the effect which an increased weight of snow would have in forcing downwards the crust of the earth into its fluid substratum.

Previous to the Glacial Period, that is during the Tertiary Period, the Gulf of Mexico extended as far north at the junction of the Mississippi and the Ohio; Florida was submerged; and an extensive belt of land on the east coast of the United States was covered by a sea having a tropical temperature. Such alterations in the coast lines must have induced a condition of climate nearly approaching, if not similar to, that which is indicated by the beds of plant-remains found in Greenland, Iceland, and Spitzbergen.

Dr. Carpenter has demonstrated that the North Polar "set" or current (commonly called North-East Branch of the Gulf Stream) is dependent on diminution of temperature in the Polar regions, causing displacement by sinking of the surface sea-water rendered denser by cooling, and the consequent influx of lighter, that is, warmer water, to supply its place. Increased severity of the winter in the north would therefore augment the volume and velocity of this current, and, *cæteris paribus*, thus render milder that of Britain. This appears to be in accordance with the persistent increase of cold in Greenland and Iceland, simultaneously with recession of the glaciers in Norway, and the occurence of milder winters in Britain; and also with changes which occasionally take place of a more temporary character, as the occurrence in America of winters of exceptional severity,

whilst the same seasons were remarkable for their mildness on the eastern shores of the Atlantic, and *vice versâ*.

Not only has the Gulf of Mexico extended far up the valley of the Mississippi, but a former depression of the land has occurred in the West Indian Islands—to 2,000 feet, and even to 5,000 feet. Raised sea beaches occur on the west coast in California, and the Gulf of California is but an extension of the Colorado Valley, which has been submerged. Subsidence to so great an extent on each side would in all probability affect the Isthmus in a similar manner. If such a depression took place in certain areas to the extent respectively of 134 and 300 feet only, it would enable the waters of the Atlantic to flow into the Pacific Ocean.

The fauna has been considered to afford indications of a former inter-communication of the two oceans; by the identity or similarity on each side, of many of the Mollusca (Mr. P. P. Carpenter, British Association Report, 1846), and also of the Echinodermata ("Depths of the Sea," page 14). It is thus more than probable that a passage for the Equatorial Current has been afforded at Panama and Nicaragua. If it occurred to a considerable extent, the North Polar Current would have had no higher temperature than that which it could derive from the Temperate Zone. Such a removal of the Gulf Stream is by most, if not all, considered sufficient to reduce the temperature to so great an amount as to cause the formation of glaciers in Britain; but, though the intense cold would condense the atmospheric moisture and cause extensive ice-floes between Greenland and Norway, there would under such circumstances have been but little remaining to be precipitated in the Arctic Ocean.

It was contended that the succession of Glacial Periods, having intervening times characterised by a mild, or even genial, climate, as demonstrated by Professor and Mr. James Geikie, might have been caused by successive depressions and upheavals of the Isthmus of Central America. To obtain positive proof of this supposed change in the direction of the Equatorial Current, it is requisite that investigations, with this object in view, be made in Nicaragua and other parts of Central America.

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PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE SEVENTEENTH.

1875-6.

(The Authors having revised their own papers, are alone responsible for the facts and opinions expressed in them.)

PART II.—VOL. III.

LIVERPOOL:

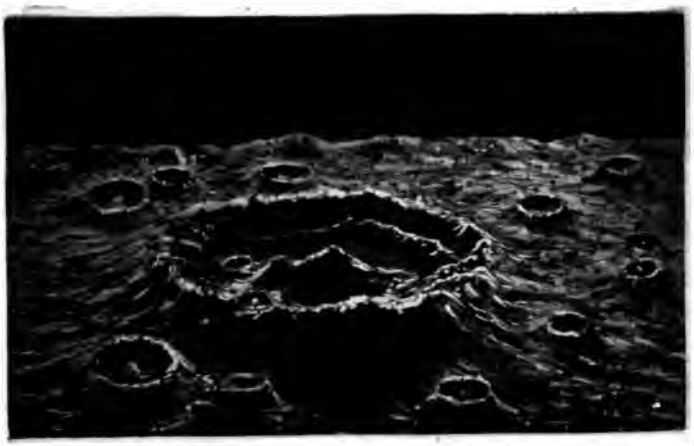
COURIER PRINTING WORKS, VICTORIA STREET.

1876.

THE MOON AND THE EARTH,

By T. MELLARD READE, C.E., F.G.S.

[See Page 86.



NORMAL LUNAR CRATER.
After Nasmyth.



SIDE-CAÑON OF THE COLERADO.
After Lieut. J. C. Ives, U.S.

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THE PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION SEVENTEENTH.

OCTOBER 12TH, 1875.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

ERNEST L. FLEMING, F.C.S., was elected an Ordinary Member.

The President read the Annual Address.

PRESIDENT'S ADDRESS.

SINCE I last had the pleasure of presiding over a meeting of this Society, a giant intellect has passed away. In the late Sir Charles Lyell were combined all the qualities necessary for the formation of an inductive philosopher of the very first rank. The position he occupied in Geological science you are familiar with. Yet, if I may be allowed to be critical with the critics, I think that his labours have not been justly appreciated: no notice of his life that I have seen appears to fully realise the extent to which modern Geology is indebted to him, to say nothing of the influence—the silent influence—his writings have had upon the philosophical thought of the age. It will take years before the focus of distinct vision is reached; and then, if I mistake not, Lyell will be recognised as the founder of the philosophy of Geology—the science of Geology in its widest aspects

and relations. In the light of the work of such practical geologists as William Smith, Sir Roderick Murchison, Sedgwick, Buckland, and De la Beche, probably many will think my views exaggerated; and it may also be said that Hutton and Playfair laid the foundations of the uniformitarian view of inorganic creation long before Lyell had directed his attention to the subject. These are names which, together with those of many eminent geologists now living, I need hardly say, I hold in the very highest estimation; but their work was of a different order: they were great and earnest workers in discovering new *facts*, while Lyell was systematising the science of Geology as a whole, and dropping down each into its exact place in his system, the facts as discovered by them and other investigators all over the civilised globe. Great geologists, of the type of Murchison and Sedgwick, distinguished themselves by their labours and perspicuity in working out the relationship of the various formations. I have heard those who can only appreciate that class of work say that Lyell was not a discoverer; never was there a profounder mistake. As I stood, at the commencement of this year, in Westminster Abbey upon the great man's grave—with the wreath by which Her Majesty intimated the estimation in which she held his name lying faded upon it—I could not help saying to myself: "This was the man to whom it was first given to clearly apprehend the relations of the natural phenomena of the earth as a whole." If the correct reading of the history of the earth is not a discovery, then Lyell is no discoverer; or, if it be argued that this history could not have been revealed to him without the labours of others, then, we may reply, neither could Sir Roderick have discovered the Silurian system without the assistance of other earnest workers in the

rocks. What Murchison and Sedgwick did for the Cambrian and Silurian systems, Lyell did for Geology. The key-note which he struck is not the doctrine of uniformitarianism, of which too much is made, but the doctrine of slow change: the building up of the earth's crust by small accretions, in opposition to the tremendous cataclysms which geologists in his early days resorted to so freely to explain difficulties. Whatever my hearers may think of the truth or otherwise of Dr. Darwin's particular evolutionary hypothesis, it is—though represented by no less an authority than Mr. Geikie as striking at the root of Lyell's uniformitarianism—to my mind but the natural off-shoot of the principles he enunciated so well. Lyell does not start with the assumption that nature has been uniform throughout all time; but that, so far as inorganic nature is concerned, as shown by the science of Geology, we have no reason for considering it otherwise than practically so. This, to my mind, is an *induction*—not an hypothesis. Lyell, evidently, was not fond of hypotheses: he knew too well how the early geologists had been misled in this way; and there are, I rather regret to see, certain signs of a relapse in favour of *à-priori* reasoning—or, a putting of hypothesis in place of fact—which we shall do well to guard against. The truth is, no mind was more open to new light than Lyell's, but he would not accept crude theories, even though they might tell in favour of his view; hence his earnest combating of the Lamarkian hypothesis in the early editions of his "Principles." Hence, also, a feasible explanation of a phenomena by reference to actual fact had more weight with him than a possible explanation by an assumption. The latter *might* prove the true explanation, but sound principles led him to prefer the

former until it was disproved. In such a tone of mind, let us trust, the great problems of Geology and Life will continue to be approached by others, and that Lyell may not have lived his life in vain.

Having now briefly referred to the labours of the author of the "Principles of Geology," and attempted to estimate the place he will occupy in the history of Geological science, I cannot render a fitter tribute to his memory than in the subject I am about to bring before you—to adhere to that true and safe mode of investigation of which he was the able and eloquent expounder. What I have said of Lyell will, I trust, form a fitting introduction to the subject matter of this address, viz: a comparison of what is known of the Geology of the EARTH, with what we can infer of the formation and history of the MOON from her surface configuration.

In looking over Professor Ramsay's memoir on the Geology of North Wales, and then reading the remarks of Sir Roderick Murchison in "Siluria"—in which he politely hints his disbelief in the ancient forms of the Snowdon range as depicted by sweeping anticlinals in Ramsay's diagrams*—it struck me that, if, as astronomers say, there is no appreciable atmosphere and no water in the moon, a comparison of the forms of the lunar surface with that of the earth would be sure to yield some interesting and instructive information. Fortunately for my purpose, Messrs. Nasmyth and Carpenters' work afforded a considerable amount of information of the kind required regarding our Satellite; and, without further preface, I will now proceed to lay before you the conclusions the comparison has led up to.

It is hardly necessary for me to call your attention to the fact that, by far, the greater proportion of rocks

* Siluria, pp. 498–9.

exposed at the surface of the earth are what is called sedimentary—that is, they have been formed by the disintegration of other rocks by atmospherical, chemical, or mechanical forces, and removed, conveyed, distributed and aggregated by aqueous action, either fresh or marine. These rocks have, I believe, been variously estimated as having an aggregate thickness of from 14 to 17 miles; but, from various causes, this thickness is very difficult to calculate.

In the first place, no system possesses the same thickness in any two places; therefore, if we add up the maximum thicknesses of the various formations—from the Laurentian upwards—we may over-estimate the thickness of the sedimentary crust of the earth, while, on the other hand, it is impossible to predicate, as Lyell so forcibly points out, that the Plutonic rocks underlying the sedimentary are not melted sediments themselves. Thus, in an attempt to estimate the part that water has played in the former history of our globe, we are met by a twofold difficulty; and the question is still further complicated by our limited knowledge of the earth's surface, that knowledge being solely confined to the continents and islands—many hardly yet explored—occupying but one-fourth of the surface of the globe. Again, as the later sedimentary rocks are principally derived from preëxisting rocks of the same character, the denudation of the one must be co-extensive with the formation of the other, denudation and deposition forming a physical equation. Thus, as you are well aware, it is only by continual upheavals and subsidences and fractures of the crust that the earth has been so uniformly covered with sediment as we find it. That these movements—consisting partly of slow variations of level over large areas, unaccompanied, so far as we know, with

rupture of the crust, and partly of movements due to earthquake shocks faulting the rocks in the way we are familiar with, and causing vertical displacements of, in some instances, thousands of feet—are due to volcanic forces, there can, I think, be no reasonable doubt.

It is not, however, my immediate object to discuss whether this action is deep-seated in a central fluid nucleus; or whether it arises from chemical action in the crust of the earth itself; or whether it be due to the secular cooling of the earth and the reproduction of heat by the falling in of the crust—a conversion of simple mechanical force into heat—as lately ingeniously maintained by Mr. Robert Mallet. From whatever cause it may arise, we know that volcanic forces—heat energy—still exists in sufficient quantity, according to Lyell, to account not only for recent changes, but for those which have taken place through the long course of Geological time, without pre-supposing that these agents were present in greater energy than now. This is what has been called by the awkward name (invented first, I believe, by Professor Huxley) "uniformitarianism." As I have before stated, Lyell never has committed himself to any statement of the *absolute* uniformity of nature: only *practical* uniformity. That these views are fully justified by our present knowledge of Geology, has been questioned lately by Professor Prestwich in his late valuable address on the "Past and Future of Geology"—but, in my opinion, without disturbing Lyell's position. Whether or not we believe that the forces of nature were more energetic or not in early geologic ages, that they were the same in *kind*, I think no one now disputes. That the centres of volcanic action shift their places over the surface of the globe, is also an admitted axiom in the mechanics of Geology. To go no further than North Wales or the

Cumberland mountains, we there find some of the earliest instances of volcanic *centres*, Silurian in age, though the cones and craters—but not lava streams—have long since been removed by that great agent, denudation, of which more anon. Then, again, we have in the Basalts of Antrim and Fingal's Cave the remains of volcanic action in the Tertiary age, with the cones and craters removed; and, as is so admirably shown in a late paper by Mr. Judd "On the Ancient Volcanoes of the Highlands, and the Relations of their Products to the Mesozoic Strata," the Granitic and Syenitic cores or bases formed originally deep down in the bowels of the earth, traversed by extensive masses of gabbro, displayed to the eye in all their complicated anatomy by nature's scalpel denudation.* Again, in the classic region of Auvergne, in the South of France, volcanic cones, pronounced by Professor Hull to be Tertiary and of the same age as the Antrim Basalts, exist almost as perfectly formed as when first built up from the ejecta of the volcanoes, though, at the same time, their enormous age is indicated in the valleys by the denudation which has since taken place.†

* Speaking of the Island of Mull, Mr. Judd says:—"The group of mountains occupying the central portion of the Island is clearly the greatly denuded core of an immense volcanic pile—the great accumulation of scoriæ and lavas which formed the bulk of this mountain mass having been to a great extent removed, and what now remains to our study being little more than the skeleton or framework of the vast pile formed by the consolidation of the springs of liquefied rock which rose through its mass."—*Quar. Journ. of Geo. Soc.*, vol. xxx, p. 248.

† Professor Hull says, in his Address to the Geological Section of the British Association, Belfast, 1874:—"But the most remarkable result of the denudation, as bearing upon the subject before us, is the complete obliteration of the volcanic cones which, we may well suppose, studded the plateaus. Some of these cones, at least, were contemporaneous with those now standing upon the granitic plateau of Central France, and which are but little altered in elevation since the fires which once burst forth from them became extinct."—p. 72.

Thus, we see, through the different action to which these volcanic rocks of the North of Britain and Ireland, and those of the South of France, have been exposed, we might, if we did not keep true to Lyell's safe mode of reasoning, infer from those in the North a greater activity and energy of the denuding agents of nature in the Tertiary times, and from the cones in the South of France but little energy of denudation from the time they were formed unto the present.

If we examine the Silurian formation in the neighbourhood of Ludlow, we not only find that the various divisions of Siluria up to the Llandovery beds occur successively without a break, but that they also lie conformably on the Cambrian rocks of the Longmynd. Mr. Hicks has also shown this to be the case with the Silurians at St. David's Head, in Pembrokeshire, and that "the sequence of rocks, of which these form a part in the promontory of St. David's, is a perfectly continuous one, from the base of the Longmynd or Harlech group to the Llandeilo group, and that in this section there are no lines of division stronger than what would naturally occur in a great series deposited over a sea-bottom becoming gradually depressed and subject to the ordinary physical influence which must have prevailed during such a change."—*Quar. Jour. Geo. Soc.*, vol. xxxi, p. 181.

The total thickness of the British Silurian rocks is 26,000 feet. They contain, in Shropshire, millions of fossils—mollusks, crustaceans, and, lastly, fish-bones, in regular order and sequence, laid down in quiet waters in undisturbed sediments, containing, about Ludlow, not even a boulder or pebble, so far as my personal examination has gone. Is it, then, not a legitimate inference that, while the volcanoes of Wales and Cumbria were active through ages longer than it is possible to calculate,

sediments were being laid down in the Silurian seas lasting over a still more lengthened period: a period long enough for one species to be succeeded by another, and to be replaced, again, by a third; so that the geologist's estimate of the time required for the sediments to be deposited over the immense area occupied by these rocks, thousands of feet thick, is reinforced by arguments drawn from Paleontology. There is nothing whatever known to me to show that these sediments were formed under physical conditions differing, in any respect, from what can be paralleled upon the earth now. The immense length of time involved in the creation of these rocks is so stupendous as to defy the human mind to grasp.*

If, then, such early rocks took so long to form, what becomes of the supposed superior energy of the forces then existent?—where is the evidence or the necessity for it? That they were formed under quiet conditions is known; for Ramsay has shown that the Silurian sediments, with their included Ash-beds, Porphyries, and Traps of the Snowdon district, were bent, plicated, compressed, and contorted by a distinct set of internal forces, long after the volcanoes giving birth to the Ash-beds and Porphyries became extinct.†

Again, to argue from another class of facts, there is hardly an instance known of a cliff produced by a fault. A writer in "Nature,"‡ describing an excursion of the

* Professor Ramsay says, in the discussion of the Rev. O. Fisher's paper on Mallet's theory of volcanic energy:—"In that sense, the Laurentian rocks are not of extreme antiquity; for the sediments of which they were formed were derived from pre-existing continents composed, as at present, of stratified and igneous rocks."—*Quart. Journ. Geo. Soc.*, vol. xxxi, p. 477.

† Ramsay's Geo. of North Wales—Memoirs of the Geo. Survey.—p. 234.

‡ Vol. xii, p. 93.

Geological class of the University of Edinburgh, has pointed out that the great fault—of unascertained displacement—traversing Scotland from Stonehaven, on the east coast, in a straight line to Arran, a distance of 170 miles, is undistinguishable on the surface, being crossed by all the rivers and some of the lakes which emerge from the southern side of the Grampians;* and this is not a solitary but a common fact. I ask, is this not another proof that Lyell was right in attributing these great faults and dislocations to repeated shocks acting in the line of least resistance, rather than to enormous catastrophes? I think it is; else the obliteration of the work on the surface should not have been so complete. In dealing with my subject so far, I feel that I have been merely stating elementary principles. There are, however, a class of deductive reasoners rather in the ascendant at present, who, arguing from two or three simple principles, demonstrate mathematically, to their own satisfaction, that such and such things *ought* of necessity to happen, and, therefore, *did* happen; to enquire whether their notions square with known facts being quite unnecessary. A knowledge of Geology would tend to make such reasoners less sure, and compel them to ask of Nature if such theories were confirmed by her records. Any theory of the earth that does not stand the geologic test—the test of reference to the earth itself—is valueless, except as a warning against hasty generalisation; and it

* Mr. Judd points out the striking instance of denudation since the Miocene afforded in the great fault of Morven, where a mass of Lias is unconformably overlain by upper Cretaceous; and this, again, by Miocene basalts, let down about 2000 feet, against the contorted gneissic rocks of the Lower Silurian.—*Quar. Journ. Geo. Soc.*, vol. xxx, p. 231.

is pleasant to find that rising geologist, Mr. Judd, insisting on the importance of adhering to the safe principles Lyell was the first clearly to expound.*

To revert again to the subject of the shifting centres of volcanic action or subterranean force, we may instance the Swiss Alps, mostly composed of Tertiary rocks; of the great Plateaus of Thibet, 14,000 feet above the sea also containing Tertiary fossils; and, lastly, what we have evidence of nearer home—the submersion of the whole of Great Britain and Ireland to a maximum depth of about 2,000 feet below the sea level, during the comparatively recent Glacial period.

Without citing further instances, it is quite clear that the earth is covered all over with signs of volcanic action, most of which is only disclosed to us by the denuding action of rain, rivers, and the sea. If we could pare off the crust of the earth, we should find them still more numerous, the roots of ancient volcanoes ramifying through the strata of various ages. Mr. Scrope, in his classic treatise on volcanoes, conceived in the truest geological spirit, states it has been variously estimated there are at the present time from 200 to 400 volcanic cones in existence, most of which are active, or have been within the historical age.† Others, we know, have been denuded, and their remains buried among the sedimentary rocks, or entirely obscured by them.

It is perfectly clear that the whole of the present continents have been not once, but often, immersed beneath

* Mr. Judd says, in his paper on "Volcanoes" (*Geological Magazine*, New Series, vol. ii, p. 3):—"In some of the latest researches on Vulcanology—to which I have referred at the commencement of this article—however, a tendency is shown towards abandoning those safer methods of enquiry based on the doctrine of Uniformity, and reverting to the earlier methods: in effect, to the substitution of Cosmogony for Geology."

† p. 11—Second Edition.

the sea, and (as is fair to assume, from the forms of the sea as displayed by soundings) that which is now sea has been not once, but often, dry land.*

It is a well-established fact that the islands of the Pacific have formed, at one time or another, vast continents. This is proved, not only by their faunas and a consideration of the geographical distribution of animals, but by the known subsidence of the bed of the Pacific, first demonstrated by Darwin in his theory of coral atolls. Not only so, but the valleys and mountains now forming the bottom of the sea, disclosed by soundings in various parts of the world, bear the impress of their sub-aërial origin; their formation, in many cases, by rain, rivers, or ice. Again, the West Coast of Ireland and Scotland, and the fiords of Norway, are further proofs of subsidence, the irregular coast line being formed by the partial submergence of valleys excavated by sub-aërial influences; and, in my opinion, the great trough, or valley, from the Cattegat to the North Cape, from 100 to 300 fathoms deep, following the coast of Norway and receiving these tributary valleys, is, in all probability, in its origin the same. To multiply instances would take up too much time; but I can refer you to my paper on the "Distribution of Land and Sea during the Glacial Period" for some further evidences.

If we consider that during the historical period Vesuvius and Etna have served as vents for the subterranean forces of Europe; that—excepting the blowing up and shivering of one cone and the building up of another within it, or the repetition of this on several occasions—the two mountains remain substantially now

* Ramsay seems to hold the view that the present continents have existed, as such from very early geological times.—*Quar. Journ. of Geo. Soc.*, vol. xxxi, p. 478.

what they were at the time of our earliest records; that it is probable they have existed as vents, before this, for a length of time immense but difficult to estimate; and that the volcanoes of Iceland may not improbably have existed since the Tertiary era: we may form some conception of the time it has taken for the volcanic energies to have travelled over the whole surface of the globe. The distribution of volcanoes in *time* would prove an interesting and fruitful investigation, and throw considerable light on the history of Geology.

In the short space of this address, it has been impossible to give more than the salient features of the Geology of the Earth from the standpoint that I have chosen; but I trust sufficient has been said to bring clearly to your minds the antithisis existing between the earth and its satellite, which I am now about to describe.

If now we turn our attention to the Physiography of the Moon, we find, from the admirable views and photographs of models made by Mr. Nasmyth of her surface,* that the side which is turned towards us presents what

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* It must not be forgotten that the moon is but $\frac{1}{3663}$ of the diameter of the earth, and the force of gravity at the surface but $\frac{1}{6}$ that of the earth; and this may assist to account for the absence of signs of violent ejection, as the ejective forces must be commensurate with the resistance met with. If the rocks are of a compactness at all similar to those of the earth, it is also evident that a greater mass might be built up with a smaller force, as the "hydraulic head" of the molten fluid would be practically only $\frac{1}{6}$ of that on the earth volcanoes. The density of the moon is also 0.62 that of the earth. I subjoin the table of data given by Nasmyth and Carpenter:—

Diameter of the Moon	2,160 miles	$\frac{1}{3663}$	that of the Earth.
Area	14,657,000 sqr. miles	$\frac{1}{13424}$	,,
Area of the visible hemisphere, 7,328,500 ,, ..			
Solid Contents	5,276 millions of cubic miles	$\frac{1}{49186}$	,,
Mass	73 trillions of tons	$\frac{1}{80}$	,,
Density	3.39 (water=1)	0·62	,,
Force of Gravity at the Surface		$\frac{1}{6}$	,,
Mean distance from Earth			238,790 miles.

has not inaptly been termed a Phlegreian field of volcanoes—so named from the *Campi Phlegræi*, the volcanic district about Naples. Instead of mountain ranges, valleys, and other irregularities such as we are familiar with on the Earth, we have the so-called lunar volcanoes in ring after ring, almost incalculable in numbers, and in sizes varying from a mile to 200 miles in diameter. This is usually considered indisputable evidence of long continued volcanic activity, such as, apparently, cannot be paralleled by anything we have experience of here. There is also this difference from the earth, *inactivity*, inasmuch as astronomers who have watched the moon say that the whole of her volcanoes are now extinct. There is also a decided general difference in the section of the rings to the volcanic cones existing on the earth; but this I will presently speak of more in detail.

To give you a general conception of the physiography of the lunar surface, I must now ask your attention to the picture map of the moon, and index map, enlarged from those prepared by Nasmyth and Carpenter. The class of features observable are four in number, and consist of crater rings—with or without central cones—the largest of which have been called walled plains; mountain chains, with occasional isolated peaks; smooth plains called "seas," with more or less irregularity of surface; cracks or fissures, occasionally forming cliffs, one valley, and bright radiating streaks. Nasmyth and Carpenter say "a higher telescopic power shows us that not only do these craters exist of all magnitudes within a limit of largeness — but seemingly with no limit of smallness—but that in their structure and arrangement they present a great variety of points of difference: some are seen to be considerably elevated above the surrounding surface—others are

basins hollowed out of that surface, and with low surrounding ramparts; some are merely like walled plains, or amphitheatres, with flat plateaus, while the majority have their lowest point of hollowness considerably below the general level of the surrounding surface; some are isolated upon the plains—others are aggregated into a thick crowd, and overlapping and intruding upon each other; some have elevated peaks, or cones, in their centres, and some are without these central cones, while the plateaus of others, again, contain several minute craters instead; some have their ramparts whole and perfect, others have them breached or malformed, and many have them divided into terraces, especially on their inner sides.

In the plains, what, with a low power, appeared smooth as a water surface, becomes, under greater magnification, a rough and furrowed area: here gently undulated, and there broken into ridges and declivities, with now and then deep rents or cracks, extending for miles, and spreading, like river beds, into numerous ramifications. Craters of all sizes and classes are scattered over the plains; these appear generally of a different tint to the surrounding surface, for the light reflected from the plains has been observed to be slightly tinged with colour. The tint is not the same in all cases: one large sea has a dingy greenish tinge, others are merely grey, and some others present a pale reddish hue. The cause of this diversity of colour is mysterious; it has been supposed to indicate the existence of vegetation of some sort; but this involves conditions that we know do not exist.

The mountains, under higher magnification, do not present such diversity of formation as the craters, or, at least, the points of difference are not so apparent; but they exhibit a plentiful variety of combinations. There

are a few perfectly isolated examples that cast long shadows over the plains on which they stand, like those of a towering cathedral in the rising or setting sun. Sometimes they are collected into groups; but, mostly, they are connected into stupendous chains. In one of the grandest of these chains, it has been estimated that a good telescope will show 3,000 mountains clustered together, *without approach to symmetrical order.* The scenery which they would present, could we get any other than 'the bird's-eye view' to which we are confined, must be imposing in the extreme, far exceeding in sublime grandeur anything that the Alps or the Himalayas offer; for while, on the one hand, the lunar mountains equal those of the earth in altitude, the absence of an atmosphere, and, consequently, of the effects produced thereby, must give rise to alternations of dazzling light and black depths of shade; combining to form panoramas of wild scenery that, for want of a parallel on earth, we may well call unearthly." With reference to the radiating bright streaks from some of the more conspicuous centres, it is proved that they do not arise from any difference of level, as they show most plainly when the sun is shining perpendicularly upon them. It is not improbable these may be dykes of a more highly reflective rock than that of the mass they have cut through. "Whatever may be the cause that produces this brightness of certain parts of the moon, without reference to configuration of surface, this cause has not been confined to the formation of the radiaing lines; for we meet with many isolated spots, streaks, and patches of the same bright character. Upon some of the plains there are small areas and lines of luminous matter possessing peculiarities similar to those of the radiating streaks, as regards visibility with the high sun, and invisibility when the solar rays fall upon them

horizontally. Some of the craters also are surrounded by a kind of aureole of this highly reflective matter. A notable specimen is that called Linné, concerning which a great hue-and-cry about change of appearance and inferred continuance of volcanic action on the moon was raised some years ago. This object is an insignificant little crater of about a mile or two in diameter, in the centre of an ill-defined spot of the character referred to, and about eight or ten miles in diameter. With a low sun, the crater alone is visible by its shadow; but as the luminary rises, the shadow shortens and becomes all but invisible, and then the white spot shines forth. These alternations, complicated by variations of atmospheric condition, and by the interpretations of different observers, gave rise to statements of somewhat exaggerated character, to the effect that considerable changes of the nature of volcanic eruptions were in progress in that particular region of the moon."

The following is a list of some of the principal craters:—

Companion to Hell	1¾	miles	diameter.
Companion to Tibit.....	2¾	,,	,,
Small crater inside "Walter"	4	,,	,,
Companion to Parot	11	,,	,,
Herschel	17	,,	,,
Godin	22	,,	,,
Vitello	24	,,	,,
Delambre	26	,,	,,
Campanus	27	,,	,,
Agrippa.....	30	,,	,,
Eratosthnes	33	,,	,,
Werner	38	,,	,,
Copernicus	46	,,	,,
Tycho	50	,,	,,
Theophilus	64	,,	,,
Alphons	70	,,	,,
Petavius	78	,,	,,

It must be remembered that, through the moon revolving on her axis exactly in the same time that she accomplishes her orbit, we see but half of her surface; but through what are called her "librations," this is increased to about four-sevenths of her surface; still leaving ample room for those who try, to imagine what her *other side* is like.

Now, what is the first idea that a consideration of these facts impresses on the mind? Probably that the moon is, in the largest sense, a "used-up" world—that, as Mr. Lockyer in one of his lectures in this town startlingly said, "the moon is dead, the earth is dying." A little investigation from the geological point of view will, however, I think, show that the "situation" he depicted is more dramatic than true, and that the inhabitants of this planet have some few crumbs of comfort left! I have shown you that volcanoes have been active on the earth through all geological time—that they are active still we all know—yet the evidences of their former profusion are not patent to every one, but must be sought for. The cones have been removed, cut down, covered up, and their bases again disclosed by denudation. The thickness of the sedimentary deposits accumulated proves that the time required to effect all these changes in the earth's surface must have been enormous. If, then, the external forms of these ancient volcanoes have been destroyed on the earth and volcanic cones are limited to particular areas, how is it that the moon's surface remains dotted all over with rings, presumably volcanic? To me the answer is obvious and clear:—In the moon there is *no atmosphere* and *no water*, and consequently no denuding agencies to remodel her surface; so that the inferences of astronomers as to the physics of the moon are strangely borne out by geological considerations. If we

are to assume, on the other hand, that, though non-existent now, there *were formerly* seas and an atmosphere to the moon, which in process of time have become dried up, withdrawn into cavities and fissures in her surface, or through her peculiar form have gravitated to the opposite side to that which we see, or in fact have done anything to escape observation—and all these hypotheses have from time to time received support from one or another eminent scientific man—I ask, where are the geologic evidences of the former existence of a sea or an atmosphere? So far as we can judge from the physiography of her surface, I answer that there are none; and that, if we are to assume their previous existence, we must be also prepared to believe that they have not only been entirely obliterated by volcanic action since, but that the volcanic action, after entirely extinguishing them, has lasted long enough to destroy all vestiges of the denuding agencies which would be at work while the water and the atmosphere existed! Let us now revert to our own world, and consider what sort of a surface she would have presented had she also had no sea or atmosphere. Here you will say we are at once involved in hypothesis, and so we are; but I think, if we agree that water and the atmosphere are the great destroyers as well as renovators of our earth—the only denuders we know of — we may safely assume that, the volcanic activity remaining as before, the earth's surface would now present a series of rings and truncated cones not altogether dissimilar to that of the moon. There is, however, one thing to be considered which complicates the reasoning: if there were no water there would be no steam, and no ejecta from the volcanic vents. This undoubtedly is the great difficulty we have to face in the comparison; but I think there are reasonable evidences

to show that steam, which, as beautifully explained by Scrope, plays so important a part on mundane volcanoes, may have been absent—nay, that there is every probability it was absent in the moon, even when her volcanoes were in full activity. When we know, from spectroscopical observations, now so scientifically carried out, that the elements of the sun and planets are identical with those of the earth, and also from meteorites (supposed fragments of asteroids), we infer that the mineral composition of planetary bodies does not materially differ from those we are acquainted with, it seems difficult to understand why the moon should be devoid of water and an atmosphere. As my object is not to suggest reasons or hypotheses, but rather to deal with facts, I must confine myself to the thesis that the geologic evidences are at one with the physical observations; and not only reinforce the truth of their declared non-existence, but also tend to prove that they never did exist. A careful study of the moon's physiography shows no instances of denudations such as we find on the earth, where, as is acknowledged by all our leading geologists, its contours of hill and dale, as we see them, are due to denuding agencies; or, to use a simile to better express the idea, the volcanic forces have provided the *blocks*, but the denuding agencies have carved them into shape. Had water at any time existed on the moon in the form of seas, most of the rings and cones would have been levelled and destroyed; vapours would have been raised by the sun's rays, and again precipitated in the form of rain: such rain would have cut gorges and valleys dissimilar to anything we see on the moon's surface. It would have corrugated the mountains, and through great rivers have carried the detritus washed from the decomposing rocks, to spread it evenly over the sea or lake

bottoms; which being in after ages upheaved, would have been again exposed to the denuders and carved into those endless forms of beauty the true lover of landscape so delights to depict: it would, in fact, instead of being a desolate mass of scoriæ and volcanic rocks, have been an earth in miniature.

What lends greater force to this reasoning, is the fact that from the revolution of the moon on its own axis only taking place monthly, the extremes of temperature of the surface exposed and that hidden from the sun's rays are intense, estimated as ranging from 200° below zero, or the supposed temperature of space, to twice that of boiling water. Is it not likely that storms of great violence, tremendous downpours of rain, and the not less destructive influence of frost arising from a range of 500° of heat, would have destroyed most of the rings and cones, and carved the surface of the moon much more rapidly than anything we see taking place upon the earth? That the volcanoes were successive and not synchronous is clearly proved by the superposition of one ring upon another, and by the numerous parasitic cones existing upon the rings themselves. If the volcanoes had emitted steam, such steam would have condensed into rain, and we should see the effect of it now on the physiography of the surface.

Again, had there been seas, the tides would have been greatly higher than those on the earth. Sir George Biddell Airy, the Astronomer Royal, to whom I have been more than once indebted for valuable assistance, informs me that the height of a tide in the moon, due to the earth and sun would be 36·18 times the height of a tide on the earth, due to the moon and the sun. This would have given a considerable amount of shore between high and low waters exposed to the tremendous extremes of

temperature named, and would have left its beach-marks permanently on the moon. It is true that the tides taking place twice a month instead of twice a day would not have possessed the momentum the earth tides have, and consequently not the same destructive force; but it is probable the revolution of the moon on her axis was at one time greater than now; and had it at any time been in the same period as the earth, though the temperature would have approached the equableness of the earth, the mere mechanical force developed by the tides would have been appalling. If, however, as Sir William Thompson and some other eminent mathematicians consider, the friction set up by tides in the particles of the fluid body act like a brake, even while the moon was in a molten state—assuming it to have been once so—its motion on its own axis would soon have been retarded, and the destructive agencies modified.

Having now given you a general conception of the differences of the earth and her satellite, geologically considered, I will, in further illustration of my meaning, consider the differences of physical configuration of their surfaces in detail.

To revert to Murchison's scepticism as to the correctness of Ramsay's outlines of the mountains of Wales in Silurian times, it is clearly demonstrable that, even were they never at any one time exactly in the form pourtrayed by Ramsay, *that material to the same extent has been removed,* and this is the main fact at present interesting us. Believing as I do that the tremendous anticlinal folds were not due to sudden and vast upheavals, but to forces acting in the same direction throughout a great length of time—vertical being converted into horizontal movement—it is quite evident that the denuding agencies, while the upheavals were taking

place, would have time to produce great results; consequently it were impossible to reproduce now, with accuracy, their exact appearance at any one stage of their formation.

To enable you to understand more clearly my meaning, I reproduce on an enlarged scale Ramsay's section from the Menai Straits through Snowdon to Arran Mowddy; showing the Cambrian grits and slates exposed by the denudation of the Merionethshire anticlinal, and also clearly proving, by reasoning based on facts and observations, and not *on à-priori* hypothesis, that no less than 20,000 feet of solid rocks, consisting of Cambrians and Silurians, with inter-bedded ashes and porphyries, up to the horizon of the Bala Limestone, have been removed before such exposure could take place. That these solid rocks were once above the Cambrians is easily understood, although the actual working out in the field of the complicated anatomy of the strata so clearly displayed in the section, required great penetration and a very comprehensive and practical grasp of geology. It is plainly seen that the whole of the rocks are conformable throughout the series—that is, they have been originally deposited in apparently horizontal planes, though now so contorted and folded. That the inter-bedded ashes and lavas are contemporaneous, Professor Ramsay has fully satisfied himself; consequently it follows that these anticlinal folds have been the result of a second series of earth movements, long after the original volcanoes had belched forth the ash beds and welled out the liquid lava enclosed between the Lingula and Llandeilo beds. Of the denudation of all the rocks between the Cambrians and the Bala Limestone the evidence is indisputable; but there is every probability that the foldings took place deep in the bowels of the

earth, when the rocks were covered with a much greater series of other rocks than any we find representatives of here. "When that contortion occurred and was finished, the mountain tops, for instance, of the Cader Idris and the Snowdon ranges were still buried deep under many thousands of feet of higher Bala beds; and at a later period, I believe, by an immense thickness of Upper Silurian Strata."—*Memoirs of the Geological Survey*, vol. iii, p. 237, Professor Ramsay also shows that the whole of Wales suffered extreme denudation before the formation of the Upper Llandovery Rocks.

The Bala Fault is estimated by Ramsay to have a throw of 11,000 feet.—p. 36, *Memoirs*.

To give another instance of denudation of a more simple character, I exhibit a section of the Wigmore Valley, near Ludlow. Without further explanation, it is quite clear that the valley occupies the site of an anticlinal, and that what is now the axis of the valley was formerly the axis of a hill. If we admit the original horizontality of the sedimentary rocks of which the flanking hills are composed, the inference of the valley being entirely due to the excavating power of rain and rivers is obvious.* I have inspected this part of the country with great interest, and not the least noticeable feature is a deep gorge at Downton, which the river has

* Sir Roderick Murchison argues.—"Siluria," p. 492—that only "very powerful currents of water could have removed every fragment of the débris that must have resulted, whether at one or several points of elevation, from the destruction of all the once superposed arches of rock, and have scooped out all the detritus arising from such destruction, from the circling depressions, the central dome, flanking ridges, and former cover of these Silurian Strata"—forgetful of the fact that a result of slow atmospheric degradation is the gradual carrying away of the waste of the rocks, either in solution in water or in the mechanical form of alluvium.—The nature of the rocks in this locality rendering them peculiarly liable to this species of dissolution.

worn through. That this ravine was formed gradually as the great mass of the anticlinal was decomposed and worn away, I am fully satisfied.

It is, of course, impossible to draw any section of the strata of the moon; but we can, I think, draw one sufficiently true in its salient features to compare its surface configuration with the typical sections of the earth strata I have just described. The section I exhibit is on the same scale as those of Snowdon, and is of the crater "Eudoxus," 35 miles in diameter and 11,000 feet deep.

A section across any portion of the moon's surface would show combinations of very similar outlines, excepting where the mountain ranges occur, such as the "Alps" and "Apennines;" and I have compared it with the usual surface configurations of the earth rather than with that of a volcanic district, to show the great difference which exists between the geology of the moon and the earth.

Without at present entering upon the controverted question of how the lunar volcanoes were formed, I ask, is it not, as I have previously pointed out, evident from the preservation of the ring-like form and the truncated cones in so many thousands of instances on the moon, and their comparative absence on the earth, that those on the moon have not been exposed to similar denuding agencies? Nasmyth and Carpenter consider that they have discovered portions of the rings of these lunar craters which have broken down and fallen into the craters; but it is just as likely that these "benches," as they are described, may have been produced by the welling up of the molten material, its consolidation at its edges in the form of "beaches," and its gradual sinking down by contraction.

One of the distinctive peculiarities of the lunar vol-

canoes is the depth of the crater, the floor of it being generally far below the surface of the surrounding surface. The absence of denuding agencies may assist also to account for this phenomenon; for if the building of the surrounding surface was continually going on by successive lava flows, and the large cauldron of molten rock rose and welled over its edges on the cooling of the fluid nucleus below, these craters' hollows would naturally result from contraction. In one case—that of "Wargentin," 53 miles in diameter—the molten matter seems to have welled up to its brim, and there consolidated in a form resembling a thin cheese. The general sinking down of the floors of the volcano beneath the general surface is no doubt also connected with the immense diameter of the crater hollows; for were we to make a section of an earth crater extended to the dimensions of a lunar one, setting the edges of the encircling rim proportionately to the diameter at the same elevation only above the general surface, we should find that the bottom of the crater would in that case be far below the general surface. If, as I have suggested, there has been an absence of denudation answering to what we are acquainted with on the earth, it is evident that the exudation of the lava on the surface would build up from the innumerable centres or vents strata upon strata of volcanic rocks. The absence of those potent carrying agents, the rain, rivulet, torrent, and river, and of that great distributer, the ocean—even though conditions of decomposition did exist—would leave the lava flows and ejecta intact, excepting to the extent that gravitation could affect the materials in distributing them as taluses to the higher slopes.

That these successive outbursts have taken place, covering the moon's surface with a stratified crust of

volcanic rocks—not possessing, however, the regularity of our sedimentary deposits—seems strengthened by the fact of the existence of what appears to be partially submerged rings, such as we see in the neighbourhood of "Wargentin." It is also not at all clear that the great surfaces (or seas, as they were formerly called) are not in all cases covered with vents which are too minute to be distinguished with the telescope.* In what are called the Lunar Apennines the ring-like vents exist in considerable numbers; and these groups of mountains have most probably been built up by long-continued exudation from numerous cracks and fissures.

A more instructive lesson than a comparison of these lunar mountains with our earth-mountains could not be found. I reproduce Nasmyth and Carpenter's plate. You will observe that there are no continuous main valleys with ramifying branches like those which the denuding power of water has traced upon our earth—no distinguishable lines of watershed and lines of drainage, such as we see so well in the shaded ordnance sheets of the Cumbrian mountains I place before you. There is no reason to suppose that these mountains—the Apennines—described as "a confused mass of broken peaks and pinnacles," are not very ancient in the moon's history; and I point to them as confirming me in my views of the absence of water on the moon at any time since they began to be formed. Out of the lips of many of the crater-like rings there appears to have been a considerable and lengthened flow of lava in one or more directions. There are also ridge-like corrugations of the surface of a very roughened aspect. There are cliffs and fissures—the latter of late origin. Many of the larger rings are

* A crater hollow less than 1 mile in diameter is indistinguishable by the telescope.

broken into by those of later date, creating "overlapping craters;" but the singular persistence of these crater-like rings is one of the most remarkable facts we have to deal with; for, had they been on the earth, even in the absence of denudation, the contortions to which the crust has been subjected would have tilted, bent, and broken them up, and entirely destroyed their symmetry.

There appear to have been cracks and fissures, but no foldings of the crust at all comparable to those which have taken place from the earliest times to the latest in the earth's geology, where strata have been, in some cases, tilted completely over, the under surface becoming the uppermost, as in the Silurians of Sibyl Head, in Ireland. Had such been the case, even without denudation, the moon would not have possessed the "pitmarked" appearance it does. So far as we can judge, not one of the rings appears to have been disturbed by internal force further than what is caused by the breaking through of other crater-like rings, and a few large fissures. This, again, seems to show that, notwithstanding her rugged aspect, the moon has been subjected to forces more regular in their action than earth volcanoes. Nasmyth and Carpenter themselves say: "We scarcely accept Scrope's term 'basal wrecks' (of volcanic mountains that have had their summits blown away) as applicable to the craters of the moon, for the reason that the lunar globe does not offer us any instance of a mountain comparable in extent to the great craters, and whose summit has *not* been blown away." Had the rings been built of ejecta thrown out of a vent, cones would assuredly have been built up of a size surpassing those of the earth, as the moon's gravitating force falls below it.

Two of the illustrations I exhibit, reproduced in the frontispiece by the aid of photography, have been chosen

as shewing the characteristic differences of the geology of the moon and the earth. That of the "Normal Lunar Crater" is from Nasmyth and Carpenter's work and the "Side Cañons of the Colorado" from the report of Lieutenant J. C. Ives, U.S., the commander of the Ives' expedition. In these copies, executed in Paynes grey, my object has been to show—though the scales are vastly different—the two scenes under the same effects of light and shade. In that of the moon we see, as I have described, the result of volcanic or fire action only. In the cañon one of the most remarkable examples of denudation the earth can present us with, in which sedimentary rocks of Carboniferous and older Paleozoic age are cut through to the granite base, and frequently 500 or 600 feet into it by aqueous action. Dr. Newberry attributes these profound gorges to river erosion, and his views are generally accepted. For 200 miles the river Colorado runs between nearly vertical walls of rock from 3000 to 6000 feet high. What a striking contrast does this not present to the surface of the moon where, as I trust I have shewn, there exists neither sedimentary rocks nor traces of aqueous denudation.

My remarks have already far exceeded in length what I originally contemplated, so, unexhausted as my subject is, I must draw them to a close. Without starting from a single hypothesis and building thereon a full-blown theory, I think we may legitimately draw the following conclusions from observed facts:—First, that the geology of the moon differs greatly from that of the earth, in possessing no sedimentary rocks; that, in the conformation of its surface, whether in mountain or crater, there is no evidence of denudation such as we see upon the earth, and that combinedly—for the one fact is strictly complimentary to the other—the evidence of the

non-existence *now* of an appreciable atmosphere or of water is not only confirmed by Geology, but that, from all we see, we may legitimately infer *that they never did exist;* that, if there was no water, there was also no steam—that active principle of earth volcanoes—and this inference is further strengthened by the fact that the ring-like craters could not have been built up of ejecta,* but rather by liquid lava welling up in huge cauldrons solidifying at its edges, and occasionally overflowing them; that there are no evidences of the folding and contortions of strata, such as we are familiar with on the earth, and that the fissures—admittedly of a late date—are due to secular shrinkage; that, in fact, the moon behaved as if subjected only to molten conditions, and that the explosions and earthquakes to which we are even now subjected had no counterpart in the moon. That there has been denudation or breaking of the rocks —due to the extremes of cold and heat to which the moon's surface is subject—may assist to account for its rugged exterior. These, I think, are all inferences probable in themselves, and not in the nature of hypothesis.

To look at the question in another aspect, the study of the lunar surface throws light upon the geology of the earth, and, by contrast, shows the correctness of geological reasoning on the subject of denudation. It also assists to prove the accuracy of Professor Ramsay's sections, even in opposition to so great an authority as Sir Roderick Murchison. There are, however, a wider set of inferences—mere suggestions, it is true, but, still, well worthy the attention of the philosopher no less than the geologist. It appears tolerably clear that the moon,

* I cannot accept Nasmyth's force of "expansion on consolidation" as capable of ejecting molten rock to the distances or with a regularity necessary to produce the rings.

in one sense, is a "spent" satellite—that her internal heat force is exhausted. Will it not, then, be said that this is a blow to the uniformitariansm of Lyell? Properly considered, I think not; for, independently of the greater length of time it would take for a planet having the mass of the earth to cool, the conservative agencies of the water and atmosphere must not be lost sight of: the heat even of the volcano is not lost by radiation into space, for the steam imparts its heat to the clouds and atmosphere, and they again impart it to the earth in refreshing showers, while the sediments accumulating from age to age must act as a non-conducting envelope; while the sea remains a distributer of heat as well as material. The moon has "run down," but we cannot legitimately infer from that that the earth will do likewise—the conditions differ. Geology tells us that the earth has existed, in a condition differing little from what she is now in, for countless myriads of years; the process of "dying" is, at all events, very slow; and, what is pretty clear, if life does become extinct and our planet dead, it will be in a way differing vastly from that of the moon.

According to geologists, volcanic action is the conservative force which retains for us our continents; and were it to cease and the earth to become rigid and inflexible, denuding agencies would level both isle and continent, and the earth would become, not without form, and void, but one uninterrupted, monotonous sea; but life—aquatic life—might still exist, so long as the earth preserved the present rate of revolution on her axis, and the sun his present heat. These may all pass away; but to contemplate such a remote and ideal picture is pure speculation, hardly within the province of the essentially common sense science of geology.

NOVEMBER 9TH, 1875.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

THOMAS LEA, RICHARD M. FOSTER, ARCHIBALD MCMILLAN, EDMUND SPARGO, SAMUEL ATKINSON, JOHN J. FITZPATRICK, J. R. WARD, and CHARLES FABERT were elected Ordinary Members of the Society.

The following communications were read:—

THE CARBONIFEROUS LIMESTONE AND MILLSTONE GRIT OF THE COUNTRY SOUTH OF LLANGOLLEN.

BY GEORGE H. MORTON, F.G.S.

This Paper forms a portion of the Author's communication on "The Carboniferous Limestone and Millstone Grit of the Country around Llangollen," which will be found at the end of the volume.

THE FOSSIL FERNS.

BY FREDERIC P. MARRAT.

DECEMBER 14TH, 1875.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

CORNELIUS SHERLOCK was duly elected an Ordinary Member of the Society.

The following communications were read:—

A NOTE ON THE THEORY OF METALLIFEROUS DEPOSITS IN VEINS, &c.

BY ALFRED MORGAN.

ON former occasions I have brought before this Society the theories that have been propounded with a view to

the explanation of the phenomena associated with those metalliferous deposits termed lodes or veins.* Two constants appear to have been established in relation to the observed phenomena of such deposits: one is the uniformity of general direction of the productive lodes in any given district, and the other is the influence of the surrounding rocks upon the contents of the veins or fissures.

With respect to the theories themselves, that least generally adopted is that the deposits have a purely igneous origin and are the resultants of sublimatory processes which have operated, perhaps, at great depths. Another view is that the fissures and other cavities now filled with metalliferous deposits were at one time the vents through which thermal waters found their way to the surface, and that in so doing they deposited layer after layer of mineral matter against the walls of the cavities and cracks through which they passed. Mr. J. A. Phillips states that this process can be actually observed in California, where highly silicious waters are forced through rents in the rocks, in which they deposit their silica, usually in the gelatinous condition; and also, he states, in this soft silica are to be found particles of iron pyrites, and even gold. The third theory (and the one, I think, most generally adopted), supposes the water to have penetrated from above; and that, in passing through the rock fissures which were the natural channels of aqueous circulation, they deposited, under what Sir H. De la Beche in the "Geological Observer" calls "rock-conditions," and what Mr. Robert Were Fox and M. Becquerel refer to electrical action, those metallic and earthy matters forming veins and other ore-deposits. Whichever theory may be held, it appears certain that

* On the Formation of Metalliferous Veins."—*Proc.* xi, 1869-70, p. 37. "Observations on Metalliferous Deposits."—*Proc.* xii., 1870-1, p. 45.

the metalliferous deposits are the resultants of the circulation of waters through fissures and cavities—which may have been natural joints or not, but were at all events originally formed—and that in passing, whether from above or below, they held in suspension the minerals that have crystallised in the metalliferous veins.

These mysterious "rock-conditions" have been called in to the aid of theories which have required of them results which, combined together as a general factor, they would appear to be unable to accomplish. Though we know little of the nature and action of these occult forces, we are led to infer that electrical energy is the directing power that regulates the deposition of metalliferous deposits as regards their localisation. This will, I think, be generally granted.

I have therefore read with much pleasure a paper by Robert Hunt, F.R.S.,* in which he details some experiments which go to show that, without calling in such aids, there exists a power capable of producing the phenomena observed. While believing in electrical energy as a powerful agent in directing the place of deposit, &c., Mr. Hunt desires to afford "evidence of the existence of a vast power common to all matter, capable of producing all the phenomena of mineral lodes." Mr. Hunt continues:—"Capillary attraction has long been known. Exosmose and endosmose action have been made tolerably familiar to us. The influences of cellular bodies in condensing fluids within them, and the absorbent powers of porous masses, such as spongy platinum, charcoal, and the like, have been repeatedly shown. It is only lately, however, that we have become acquainted with the facts, that a certain thickness of silicious sand will separate salt from its solution in water, and that agricultural soil

* Trans. Roy. Geol. Soc. of Cornwall, vol. ix, part i, p. 22.

deprives the water percolating through it of the organic matter dissolved in it. M. Edmond Becquerel has lately shown that if two plates of glass are so arranged that by touching at one end and being kept slightly open at the other, so as to show the capillary curve of attraction, and if between these plates we pour a solution of some mineral salt in water, that the surface force will separate the metal from its chemical combination and attract it to the surface of the glass, on which it will be deposited as a metallic film."

Acting upon this suggestion, Mr. Hunt made a few experiments, with the idea that if he could produce a state of unstable equilibrium in the chemical solution, the metalliferous deposit might be induced to take place upon surfaces widely separated. He says:—"By adding to a solution of cyanide of silver a very small quantity of an hyposulphite, quite insufficient to produce a precipitation, the surface action of the sides of a pint bottle was sufficient to produce this deposition, in the form of a coat of sulphate of silver.

"Aldehyde and grape sugar have a similar power; with porous vessels this condition can be most readily established, and most beautifully so, by the action of charcoal. By putting a piece of freshly-burnt charcoal into a solution of nitrate of silver we obtain in a little time very beautiful crystals of silver, which are entirely due to the influence of the surface force, distributed over the molecules of carbon arranged to form the cells of the carbonised wood."

Though experiments are yet required to determine the extent to which this surface force may be brought into action, we have afforded by these experiments a clue, perhaps, to the unravelling of some of those secrets which, notwithstanding the student's earnest questionings, Nature still holds in her inexorable grasp.

NOTES ON THE RELATION BETWEEN THE MINERAL FLINT AND THE COUNTY OF FLINT.

By George H. Morton, F.G.S.

The occurrence of chert in the Carboniferous Limestone is well known, though, perhaps, the difference between chert and flint is not generally understood. Chert is an impure flint, and usually contains lime. It also differs from flint in breaking into square splintery pieces instead of a conchoidal fracture. An analysis of this very common mineral, found near Holywell and Flint, in North Wales, proved it to be flint rather than chert, and much of it is certainly flint in appearance, but only certain portions of it. That the mineral flint should occur most abundantly in the county of Flint is very remarkable, but it is equally remarkable that Mold (mould) should occur in Flint. But the question is, whether there is any connection between the mineral flint and the name of the town and county, or whether the latter was so named by chance without any object; which, however, is unlikely. We may safely conclude that flint the mineral and Flint the name are one and the same word. The Saxons probably gave the name to the county, for the word flint is of Teutonic origin; although some authorities have referred it back to the Greek. The German is *flintenstein*, or fire-stone, so that so far as the origin of the word is concerned it is possible enough. There might have been some difficulty if there had been a Welsh word *fflint* meaning something quite different to flint, but there is no such word in the language. The subject has evidently attracted attention before now; for Pennant, in his "Travels in North Wales," says:—

"I cannot assign any derivation of the word; our country is totally destitute of the fossil usually so called. I can only remark that it is purely Saxon; and, notwithstanding it is not mentioned in the Domesday Book, was called so before the Conquest." It is strange that Taylor, in his "Words and Places" the best book on the subject—does not mention Flint. However, in Charnock's "Local Etymology," the following occurs:—"Flint, the county town of Flintshire, N. Wales. Pennant remarks that this town had an early origin, and although not mentioned in Domesday, that the name is Saxon, and that the spot was so called anterior to the Conquest; but as the country produces none of those accompaniments of chalky strata denominated flints, he is at a loss for the derivation. Upon which a later writer [*no reference given*] observes that when Flint was made one of the four N. Wallian counties, in the time of Edward I, the statutes were promulgated in barbarous Latin, and the county was in some instances called Comitatus de Flint, which was probably a translation or various mode of expressing in writing Comitatus de Silici, or the silicious territory; chert, which the ancients designated both by the name of *silex* as well as *petrosilex*, being a predominant feature in the geology of this district. He suggests also that it may be the Brit. *fflwyn*, a shred, a severed part; a name the independent Britons would naturally give it after the inhabitants had submitted to the Roman yoke, which, from historical documents, they appear to have done long prior to the other subdued parts of Cambria." The question, therefore, is—Whether the mineral occurs in such abundance that the town or county would be likely to be so named in consequence. It can scarcely be considered to be remarkably abundant, so that I am inclined to think it might be rather on account of its relative

abundance; for on Halkin Mountain flint is actually quarried from regular beds ten feet in thickness, and sent to the Potteries, where it is largely used in the construction of grinding floors. According to Pennant, it was used for the same purpose in his time. The locality is three-quarters of a mile W. of Pentre Halkin, which is two and a-half miles from Flint, and the same distance from Holywell; and there can be no doubt that the silicious strata were much more conspicuous before they were worked along their outcrop. However, chert or flint occurs in the upper beds of the Carboniferous Limestone throughout the whole length of Flintshire, though more fully developed in the locality described. Certainly the mineral occurs in other Welsh counties, but I have never seen any deposit at all to be compared with the silicious strata near Flint. If flint was in request for any particular purpose in Saxon times, if only used as a means of obtaining a light, and was far more abundant in the hills along the side of the Dee than in other places, it seems likely that the county might have been named Flint in consequence. It may be difficult to prove that it was so, but it will be just as difficult for any one to disprove it. It is curious, too, that if Flint be a Saxon name, it is the only Welsh county that has a Saxon one. but this is not a strong objection against it, for there are many places about the town of Flint the names of which are undoubtedly of Saxon origin; and it is not more extraordinary that Flintshire should have a Saxon than Beaumaris should have a Norman one. Though I am not altogether inclined to adopt this origin of the name of the county, it appears to me that it is very likely, and that the subject is worth further consideration. Probably the foregoing observations may elicit additional information.

THE LOWER LIAS OF STREET, SOMERSET.

By T. Mellard Reade, C.E., F.G.S.

The County of Somerset presents a striking contrast in its scenery to that of Lancashire, and both are instructive as shewing how intimately related landscape is to Geological structure. To one who has worked at the Trias in this neighbourhood it is doubly interesting, for in addition to the striking contrast between the paleontological barrenness of the New Red rocks of Lancashire and Cheshire, in which the only fossils are the imprints of the Cheirotherium footsteps, and the wonderful richness of the ammonite beds of the Lower Oolites (or, as some will have it, the Upper Lias), in Dorset, on the borders of Somerset, at Bradford Abbas and Sherbourne, we have in Somerset the connecting links between the Trias and the over-lying fossiliferous rocks.

In a cutting in the Somerset and Dorset Railway, between Midsumer Norton and Shepton Mallet, I had the good fortune to see the passage beds between the New Red Marl and the Lower Lias, consisting of the Rhætic Clay and Shales, with the *Avicula Contorta* bed well exposed and overlaid by the Rhætic White Lias, containing the Landscape Stone so well known to collectors, and again by the Lower Lias. In a descending order also were the grey and red marls of the Trias, the Dolomitic conglomerate hitherto classed with the Trias, but uncommonly like Permian, containing great fragments of the Carboniferous Limestone, with most interesting hollow nodular concretions lined with quartz crystals, splendidly-coloured pink, by a hematitic iron deposit

on their surfaces. The base rock of the whole, the Carboniferous Limestone could also be studied with advantage.

In the neighbourhood of Street, a village about one and a half miles south-west of Glastonbury, there are several quarries in the Lower Lias, and the section of one of these it is my present object to describe. I have seen the Lower Lias at Lyme Regis on the south coast, and at Watchet on the Bristol Channel, and there is, without pretending to trace the individual beds, a striking lithological persistency in the character of the rocks. They are remarkable for thinness, regularity, and parallelism. At Watchet, where the beds dip towards the Bristol Channel, a large expanse on the shore looks more like masonry in the regularity of its main jointing planes and the "breaking joint" of its cross jointing.

The bottom of the quarry must be pretty close to the Rhætic beds, though they are not actually reached, as the Red Marl shows on the other side of the hill to the south, not far off. The stone is quarried for "paving," or what we call here "flags," and it seems, from the regularity with which it splits, well adapted for the purpose. A good many Icthyosaurian remains have been taken out of the quarry and carefully put together and cleaned-up by the proprietor, Mr. Josiah Seymour. Among these not the least interesting is the *Icthyosaurus Communis*, which I obtained for the Liverpool Museum, remarkable as possessing perfect, even the small terminal vertebra of the tail. This specimen, together with most of the others, was obtained from what is called the Principal Shale, 8 inches thick only, not far from the base of the quarry. The following is a description of the section which gives

one a good idea of the stratigraphical character of the Lower Lias, consisting as it mostly does of beds of Blue Limestone, with partings of Shale, and beds of Argillaceous Shale:—

	Ft. In.
Clay and Soil	1·9
Yellow Stone	0·9
Clay (Reptiles, *Icthyosaurus*, &c.)	3·0
Top Rock (in 4 beds), Building Stone..	2·6
White Stone	0·6
Creams	0·4
Red Livers	0·3
Black Stone	0·4
Six inches	0·6
Four-inch Bed	0.4
Blue Clay	0·11
Principal Shale (*Icthyosaurus Communis*)	0·8
Grey Clay	0·9
Blues (2 beds)	0·8½
Top Fires	0·4½
Bottom Blues	0·4
Thick Fires	0·8
Shale	0·9
"New-found-out," Fish, *Cycads*, Rain drops, thickness not stated.	
Total	15·5

REMARKS ON THE COUNTRY AROUND THE WREKIN.

By Charles Ricketts, M.D., F.G.S.

In directing attention to the country around the Wrekin, it is not intended to give a detailed account of the Geology of a district already so well known, nor am I aware that I shall be enabled to bring forward any new facts; my desire is rather to place phenomena observed there in a different light, and, comparing them with those of other districts, to use them for the illustration of principles—some not as yet generally accepted—which I have had occasion to bring before the notice of the Society on various occasions.

The Wrekin, which rises a conspicuous object above the surrounding country to the height of 1320 feet, consists of a volcanic mass which has, in its passage through a rent formed in the Caradoc rocks, converted the sandstone strata into quartzite. It extends in a direction from N.E. to S.W. for about three miles; being, independently of the hardened quartz rock flanking its sides, a quarter of a mile wide at its greatest breadth, but becoming narrower at other places to less than an eighth of a mile. The character of the rock varies, being hard and compact where a little stream has cut for itself a channel dividing the hill into two parts, and through which the road to Wellington passes; whilst at its northern extremity, at Ercal Wood, it forms large rounded masses of a red colour, which, by weathering, separate in concentric coats, these again breaking into small pieces make a good substitute for gravel, in place of which it is extensively used.*

* "A similar rock forms the nucleus of Primrose Hill, at the south-western extremity of the range."—"Notes on the Geology of North Shropshire," by Charlotte Eyton, p. 18.

If the direction of the longer axis of the Wrekin is extended for about nine miles, the line will pass very nearly into the eruptive rocks of the Lawley and Caradoc Hills. This "long line of dislocation and faults extends for 65 miles, from Coalbrook Dale, S.W., to the neighbourhood of Gladestry, in Radnorshire."* So that, as modern volcanos occur along definite lines, their "great trains of vents, indicating the existence of extended fissures or lines of dislocation across the earth's crust, through which subterranean igneous matter has for a vast series of ages been habitually protruded," † it may be presumed that these ancient ones have been situated along similar lines of weakness; but, as now, so also then, the fissures along which the vents have occurred did not permit the molten rock to pass entirely through the earth's crust, from the interior to the surface, along its whole length, otherwise a dyke would have extended the whole distance between the different foci of eruption.

There is no evidence remaining to indicate the period when the volcanos near Church Stretton—the Lawley, the Caradoc, and Cardington Hills—were in a state of activity; every trace of the accumulation of ashes and lava which once issued from these volcanic vents has been removed by denudation, which occurred previous to the subsequent deposition of any stratified rock now remaining. With respect to the Wrekin, it is different. Extending parallel to it for nearly its whole length, but separated by a space of from half a mile to a mile, there are displayed on its eastern side the remains of a succession of bands of basalt and volcanic ash; the latter, by the innumerable volcanic bombs with which it is studded, seen along the road as it approaches Little

* Professor Ramsay.—"Horizontal Sections of the Geological Survey," sheet 54; Explanation, p. 1.

† "Volcanos," p. 258.—G. Poulett Scrope, F.R.S.

Wenlock, indicates the near vicinity of the crater from which they had been ejected; and the irregular and unstratified manner in which they lie embedded, with no stratified deposits intervening between the beds, proves that the eruption had been subaërial. The bombs are extremely like, both in size and appearance, many of those ejected during the progress of making steel by the Bessemer process. At Harris' Coppice is another ash-bed, apparently near to if not forming the base of the eruptive rocks, containing an abundance of small grains and lapilli; it has a bed of basalt resting upon it, both being overlaid by Millstone Grit.

These eruptive rocks lie successively on the eroded surfaces of the Caradoc and of the basement beds of the Upper Silurian strata, that is, upon the May Hill Sandstone and Conglomerate, and the Wenlock Shale; so that not only did the eruption take place after the deposition of the Old Red Sandstone, and the exertion of that power which has resulted in the tilting up, at a considerable angle, of it and the underlying strata, but also subsequent to the denudation by which even then the whole series, from the summit to the base, were displayed in this neighbourhood within an area of five or six miles. It is, in fact, to causes which were in action prior to the deposit of the Carboniferous strata, that the more prominent features in the present contour of this district are chiefly due.

Though the displacement and upheaval of the older stratified rocks occurred previous to the intrusion of what is now the Wrekin, the presence of this hard and unyielding mass appears, upon the occurrence of subsequent changes, to have had influence in determining the foldings which exist in the Carboniferous rocks of Coalbrook Dale, causing them to take place in a direction parallel to that of its longest axis.

Resting upon the lava and ashbeds is a bed of limestone, quarries of which have been opened in different places along the outcrop, extending from Little Wenlock in a northerly direction for about two miles; the occurrence in great abundance of *Productæ*, characteristic corals, and other fossils, refer it to the Carboniferous Limestone series. At its southern extremity, in Oldfield Quarry near Little Wenlock, the strata lie horizontally; but at Hatch they dip to E.S.E. at 22°, and at a higher angle further north. The limestone proper is, at the southern portion of the area, only 20 to 25 feet thick; and at Steeraway, further north, the vertical section of the Geological Survey makes it 40 feet; so that, compared with other districts, the thickness of this limestone is remarkably small. With the exception of a small area at the northern extremity of the Coalbrook Dale coal-field, and at the Titterstone Clee Hills (to be referred to hereafter), the nearest place at which the Carboniferous Limestone exists is Llanymynech, 30 miles distant to the north-west; Mr. G. H. Morton, F.G.S., calculates that its thickness there is about 400 feet, and has informed us that nine miles further north it gradually dwindles down to about 100 feet.* It again increases to 1,000, and even to 1,500 feet, in Denbighshire.† At Llanymynech it must have been deposited in a hollow formed in the older rocks—I should consider it to have been in a submerged valley—situated between the Breidden Hills and the extension of the Longmynd northwards on the one side, and the hilly country north of Llanfyllin on the other. A subsidence of all this land has taken place gradually and progressed simultane-

* Proceedings of the Liverpool Geological Society, 1875-76.

† "The Coal-fields of Great Britain."—Professor E. Hull. Second Edition, p. 99.

ously with the deposition of the limestone strata; the area about Llanymynech having been submerged, as is shown by the greater comparative thickness of its limestone, ages before that of its own extension northwards, or before the area of Little Wenlock reached the sea level; whilst the higher hills must have formed promontories, and some perhaps small islands, situated in a Carboniferous sea.

The limestone passes upwards into beds of sandstone and carbonaceous shale, having together about the same thickness as it. This estuarian deposit consists of materials such as might have been derived from the disintegration of the older rocks of the neighbourhood, and is referred to the Carboniferous Limestone series. Though at Oldfield Quarry these deposits are from 40 to 50 feet thick, there is nothing to represent them at Harris' Coppice, at a mile distance to the south on the Little Wenlock road, unless it be a band of muddy sediment not more than an inch in thickness; beds of conglomerate (Millstone Grit) lying immediately on the basalt and ash-beds. Bosses of igneous rock rise through the Millstone Grit at various places, whilst "others have been discovered in the deep workings."* So that the intrusive and erupted volcanic rocks, which had even then suffered much denudation, will have appeared above the level of these sedimentary deposits; and, if not forming islets during the deposition of the Carboniferous Limestone, they would at a later period, when the land was further depressed, during that of the Millstone Grit, in a manner similar to the small islands formed of volcanic rock situated in the Firth of Forth.

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* "Geology of Coalbrook Dale," by Joseph (now Professor) Prestwich.—*Proc. Geol. Soc.*, vol. ii, p. 403.

The transition is sudden from the strata which have been referred to the Limestone Series to that of the Millstone Grit, the basement beds of which are conglomerates composed of rounded quartz pebbles. At one place the shales upon which they rest had rootlets passing from its upper surface perpendicularly downwards *in situ* as they had grown; so that this then surface of low-lying land must have subsided below the sea level, possibly was also partially denuded, thus permitting the deposition of materials which had been derived from a different and distant source. I traced the Millstone Grit of this district to its farthest extent southwards at Barrow, a farm two miles due east of Much Wenlock, where it overlies respectively the Upper Ludlow Shales, and the Old Red Sandstone; whilst near the Wrekin, at Harris' Coppice, where the Carboniferous Limestone does not exist, it rests upon the erupted matter which has issued from the volcano of the Wrekin.

These grits and conglomerates are eighty feet thick at Steeraway and form the base upon which the measures of the Coalbrook Dale Coalfield rest. Their margin indicates the extreme limits of a bay which the Carboniferous Sea occupied; the Longmynd, the Stiper Stones, and the Breidden Hills constituted a promontory separating it from the Oswestry district, where the Millstone Grit is, according to Mr. Morton, about 560 feet thick; whilst Wenlock Edge and its overlying Ludlow rocks and Old Red Sandstone formed an isthmus, dividing it from the bay in which was deposited the Limestone and Millstone Grit of the Titterstone Clee Hill. But in South Staffordshire the Coal-measures rest directly on Upper Silurian strata, so denuded that they overlie the whole series from the base of them, or May Hill Sandstone, near Barr, to the Aymestry Limestone at Sedgley; it therefore

seems certain that this land extended to the eastward by Dudley and Walsall, through Warwickshire to Leicestershire, and, though depressed to, or even below, the sea level, was never submerged during the Carboniferous period.*

The Clee Hills, situated on the southern side of this ancient isthmus, consist of several detached patches of Carboniferous rocks, resting upon Old Red Sandstone, which have been preserved from destruction by cappings of basalt. The more northern of these areas consist of Coal-measure strata only, whilst the Titterstone Clee Hill is composed also of marine beds of the Carboniferous series—Carboniferous Limestone and Millstone Grit. The Limestone differs most materially from any found further north, being characterized by an oolitic structure which, in a quarry to the north-east of Knowl, extended through its whole thickness, 25 feet; the shells contained in it having been broken into such small fragments that it was impossible to identify any. This oolitic character, common also in the Bristol area, indicates a great difference in physical conditions during the deposition, between what was here a submerged area forming a shallow bay and the sunken hilly districts farther north.† The Limestone of the Titterstone Clee Hill, was overlaid by about 60 feet of Carbonaceous Shale prior to the deposition of the Millstone Grit.

* The fact of this ridge existing during the Carboniferous period as a division between two seas, was demonstrated by the late Professor Jukes in "Memoirs of the Geological Survey—South Staffordshire Coal-field," preface, page xiii; and by his successor in the Geological Survey of Ireland, Professor E. Hull, in "The Coal-fields of Great Britain," page 108, and in *British Association Reports*, 1870, page 75, where he also shewed that the northern boundary of the Coal formation to the north of this central barrier was formed by the Cambro-Silurian rocks of the Lake-district and portions of the "southern uplands" of Scotland.

† Mr. Morton informs me that some of the beds of limestone in the Llanymynech district are oolitic in structure.

The land which, at the commencement of the formation of the Coal-measures, was, near Coalbrook Dale, the boundary of the Carboniferous sea, rose from its shores to a considerable elevation above its level, as at Benthal Edge, Wenlock Edge, the Longmynd, and towards the Breidden Hills; a marine plain formed of the conglomerates and sandstones of the Millstone Grit being the base upon which they were deposited. During the earlier period of their formation the accumulation was neither very great, nor the subsidence considerable, when compared with other coalfields, the partings between the lower or workable beds of Coal being thin, and the deposit chiefly consisting of a fine ferruginous clay. Taking the section at Lawley as given by the Geological Survey* (and it very nearly coincides with other sections, and with information derived from workmen) the strata in which the profitable Coals lie, from the Top Coal to the Little Flint Coal, is 180 feet thick, containing thirteen beds of Coal amounting to 40 feet in thickness, and the measures to 140 feet, being a marked contrast when compared with those of other districts. Professor Hull states that in Denbighshire the Middle Coal-measures, which are the only ones worked, have in a thickness of 800 feet of strata an aggregate amount of from 27 to 30 feet of workable Coal, the lower measures, about 1000 feet thick, having several seams varying from 2 to 3 feet, but are little sought after in the presence of the thick seams of the middle series.† Professor Hull states that in the St. Helens district the strata from the Lyons Delf to the Arley Main Coal is 1807 feet, with an aggregate of 59 feet 6 inches of Coal,‡ and observes that

* Vertical Sections, Sheet No. 32.

† *The Coalfields of Great Britain.*—By Professor Edward Hull, Second Edition, pages 99 and 100. ‡ Page 124.

"there is a general thickening of the sedimentary materials, as sandstones and shales, to the N.N.W. Thus the same coal-seams are farther apart at St. Helens than at Prescot, and at Wigan than at St. Helens."* The Lower Coal-measures or Gannister beds are 1800 feet with 6 or 7 seams of coal, seldom of greater thickness than 2 feet for each.†

Professor Jukes has conclusively proved that the *Thick or Ten-yard Coal* of South Staffordshire, which, in the neighbourhood of Dudley, consists of thirty feet of coal without any or with but very thin partings, is, five miles to the north of Bilston—at Essington and Wyerley —represented by ten beds of coal and interposed shales and sandstones, amounting together to the thickness of 300 feet. The aggregate thickness of the coal is the same, the increase being entirely due to the amount of sedimentary materials between the beds.‡ It may, I consider, be inferred that at the southern portion of the district, near the summit of the ridge previously referred to, the land, during the period of the growth of the enormous amount of vegetation forming the "thick coal," continued persistently stationary; whilst towards the north, that is, somewhat nearer the source of the sedimentary deposits, there was a gradual and progressive subsidence, which proceeded in a greatly increased ratio further northwards.

Where the Measures in Coalbrook Dale are situated above the Millstone Grit, they contain many valuable beds of coal, whilst those formed later and upon old land surfaces, extending southward to the Forest of Wyre and from Caer Caradoc by Shrewsbury to Alberbury, are of a comparatively "valueless nature," containing at the most

* Page 123. † Page 127.

‡ "Memoirs of the Geological Survey—South Staffordshire Coal-field."

only "two or three coal-seams not of sufficient value to induce mining operations far from the outcrop." "The strata belong generally to the higher part of the coal series which throughout England is but sparingly enriched with beds of coal."* The contrast between the different coal-fields is remarkable; the one studded all over with numerous shafts, the other with but here and there evidence that coal has been "gotten," and that generally consisting only in the bank of a deserted colliery.

It has been shown that, prior to the eruption of a subaërial volcano (whose vent is now represented by a portion of the igneous rock which constitutes the Wrekin), the Old Red Sandstone, the Upper Silurian and the Caradoc strata had been upheaved and extensively denuded; and that remains of the materials ejected are distributed on the eroded surfaces of the two older formations. The northern extremity of Wenlock Edge and of the Longmynd constituted higher ground encircling this area, which by depression formed a bay; these same hills became an isthmus separating it from another bay situated a few miles southward, its most northerly extension being the Titterstone Clee Hill. The erupted rocks had undergone a considerable amount of denudation previous to their depression beneath the sea. That this subsidence was gradual, and occurred towards the termination of the period of the formation of the Carboniferous Limestone, is indicated by its being much greater in thickness at Llanymynech, and especially farther north, compared with its small amount here, where it is at the utmost eighty feet, and thins out entirely within a very short distance.

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* *Idem*, pp. 91–92.

There are in various other places indications of the Carboniferous Limestone having been deposited in areas which had previously been more ancient valleys, as in Anglesey, near Denbigh and Llangollen, and in Cumberland, where the base of the Carboniferous series is not unfrequently represented by what has been erroneously designated Old Red Sandstone, now recognised by the staff of Her Majesty's Geological Survey as "Carboniferous Basement Beds;" "they contain fragments derived entirely from rocks which are seen in the immediate neighbourhood,"* and the limestone lies conformably upon them; whilst, in the different districts, it may be seen within a short distance resting on the eroded surfaces or edges of older rocks. It is more than probable that these conglomerates and sandstones are situated in the bottoms of ancient valleys, and were deposited near the mouths of their rivers. As depression progressed these strata were overwhelmed by the sea; and the valleys, changed into estuaries and bays, permitted the limestone to be deposited on their flanks, filling them up entirely, and this continued until the ridges even were deeply buried beneath it.

The origin of any extraneous materials the Carboniferous Limestone contains may also with probability be referred to the disintegration of land in the neighbourhood; but its large area and great thickness indicate the prolonged degradation of some large continental area

*Mr. (now Professor) T. McK. Hughes, when referring to these strata in Westmoreland and Cumberland.—*Memoirs of the Geological Survey—Kirkby-Lonsdale*, p. 15. Mr. J. Goodchild, of H.M. Geological Survey, also says that in the valley of the Eden this basement series "seems to be mainly composed of locally derived materials."—*Quart. Journ. Geol. Soc.*, vol. xxx, p. 396. Mr. Tiddeman has remarked that the Mountain Limestone is 3,000 or 4,000 feet thick in the Lake district, and in the Pennine chain, at a distance of 15 miles, only 600 feet.—*Quart. Journ. Geol. Soc.*, vol. xxx, p. 400.

during the period of deposition.* The *débris* must have been carried by its river as sediments into the sea at some locality unknown to us; whilst the lime, held in solution by its waters, was at the same time conveyed and distributed by currents, being utilised where found by corals, mollusks, and other organisms, or was otherwise deposited.

The effects produced were immense, though the physical changes which induced them may have been small, by which the great submarine plateau of Carboniferous Limestone became the basis on which were distributed materials as different from it as are those which constitute the Millstone Grit (including also, under that term, the Yoredale series of rocks), and those which were subsequently deposited—the delta-formed strata of the English Coal-fields. The abundance of mica and of quartz in these deposits, refers their origin to the disintegration of granitic or gneissic rocks, probably of an extensive mountain range; whilst the Coal-measures must be compared to the delta of some large river, on whose alluvial plains grew the abundant vegetation now represented by the various beds of coal; the clays, shales, and sandstones being mud and sand which overspread these plains when the river overflowed or broke through its banks.

The circumstance of the general and persistent depression of the bed of the sea as the accumulation of limestone progressed, and the fact that, in the neighbourhood to which especial attention is being directed, there was an isthmus sixteen miles wide, forming a division between two seas,† may afford a clue to determine the

* "In the open sea, at a distance from any land, lime is said to be rarely, if ever, discoverable by analysis."—Jukes' "Student's Manual of Geology," 1862, p. 125.

† It was reduced to twelve miles during the deposition of the Millstone Grit.

circumstances under which these changes have taken place. The abundance of the lime must have required the existence of a large river flowing through a limestone district, emptying itself into the sea, probably within at the utmost a few hundred miles of the place where the limestone has been deposited. This proximity is not an absolute necessity, for the lime in the *globigerina* ooze of the mid-Atlantic has its source in the great rivers of America. A large river was needed to convey the sand, mica, and mud of the Coal-measures from the gneissic and granitic mountains from whose disintegration they have been chiefly derived, and which, as the river overflowed or broke through its banks, and as subsidence of the land progressed, overwhelmed the alluvial plain with waters holding in suspension all but the coarser sediments. A large river would also be required as a means by which the materials derived from the same—at all events, a similar origin—forming the Millstone Grit, might have been brought within the influence of the action of the sea. Many of its particles are much coarser than any found in the Coal-measures; its sands and grits are to a great extent more or less angular, and must have been carried along by the rapidity of the stream without much friction; whilst the larger fragments of quartz are invariably rounded, probably as a result of exposure to constant friction by being pushed along the river-bed. They were subsequently distributed by tidal and other currents over the bed of the sea; filling up the space between the upper surface of the Carboniferous Limestone almost to the surface level of the sea, and, though there was a considerable amount of subsidence continually taking place whilst this accumulation was progressing, they sometimes, as in Yorkshire, formed low-lying land, which remained

above the sea-level sufficiently long to admit of the growth of vegetation to produce beds of coal. The beds of coal interstratified with the Yoredale shales and Millstone Grit of Penygent may be cited as examples. This *débris* would also have been carried into bays, like that at Coalbrook Dale, where they would have been distributed in a similar manner to the sands in Morecambe Bay, derived chiefly from the degradation of the Triassic rocks of Lancashire and Cheshire, forming a plain at a level between high and low water mark.

A difficulty arises in determining the causes by which the barrier was removed between the Carboniferous sea of the north-west of England and the great river, whose existence I think is certain, but its course unknown. An isthmus, as has been shown, divided this great northern bay from another situated further south, the elevation of the ridge between them being so small that, had subsidence progressed there during the period of the marine deposits of the Carboniferous formation, to an extent moderate compared with what occurred in other places, a junction or strait must have been formed between the two seas. Let us suppose a circumstance somewhat similar, and not unlikely to have happened. That the marine area, in which the Carboniferous Limestone was being deposited, was separated by a ridge or range of hills from the valley through which the supposed large river flowed; the limestone area we know was persistently subsiding; and, if there was much sediment brought down by the river, judging from what is observed in so many great rivers, subsidence would take place and a delta be formed at its embouchure.* This depres-

* The St. Lawrence, in consequence of the detritus being detained in numerous extensive lakes, *may* be an exception.

sion would continue as the accumulation progressed, so that the valley would be entirely filled with the deposit forming the delta and alluvial plain; and the bed of the river might also become somewhat higher than some lower portion of the ridge. The tendency would then be for a channel to be formed communicating with the bay, which, uniting with the main stream, would, according to its size, divert into it a large portion of materials such as had previously passed into an adjoining sea.

Though there is no known deposit during the Carboniferous period which can be referred to delta-accumulations, such as have been supposed, the suggestion may be made whether the Calciferous Sandstone series in the neighbourhood of Edinburgh may not represent sediments which have filled up the valley formed by a large tributary of such a river. These strata amount altogether to a thickness of 3,500 feet; and they, as well as the Carboniferous Limestone and Millstone Grit, have been formed under conditions differing in a most marked manner from those deposits in England which have been under consideration and are referred to the same periods.

The diversion of a continental river into such an area as that occupied by the Carboniferous Limestone, however it may have originated, would have brought into it the *débris* derived from the degradation of the land, which would have been distributed over the bed of the sea by tidal and other currents. As deposition went on, depression of its bed would have progressed, not always continuously in any single locality; for sometimes, as in the Yoredale series and Millstone Grit of Yorkshire, it became filled up to the surface level of the sea, and land surfaces were formed, on which vegetation flourished, so as to form beds of coal; such surfaces subsequently

became depressed and covered with other beds of micaceous shales, sandstones, and grits; and this process was repeated many times in succession. In some districts the total thickness of these sediments amounts to 5,000 feet; whereas at the extreme limit of the bay at Coalbrook Dale, where they overlie the Limestone, but were in the immediate neighbourhood of land, they are represented by 80 or 100 feet only; thinning out entirely at Barrow Farm. This slight subsidence may be due to the accession of pressure from accumulation occurring from one direction only, whereas at so short a distance as thirty miles, at Llanymynech, where a greater thickness of Limestone indicates the existence of a more expansive sea, the accumulation amounts to 560 feet.

The *débris* brought down into this sea overspread and filled up the whole area until, subsidence ceasing to progress in equal ratio with the deposition, no more was distributed from seaward, and the stream passed along a channel in this marine plain. In the subsequent deposits, forming the Coal-measures, there are sandstones and shales, with abundance of quartz and mica entering into their composition, similar in character to those in the Millstone Grit; they may therefore be referred to the same origin, but the grittier and coarser particles are wanting, and there is an entire absence of the rounded quartz pebbles. These pebbles must, with other materials, have still been propelled seaward; but portions, which consisted of such fine materials as were capable of being suspended in the current, were deposited upon the inundated plain when the river broke through or overflowed its banks.

By comparing the delta-deposits of the Coal-measures with those of large rivers, such as the Mississippi, it will be perceived that, though the bursting of the banks would

have overwhelmed the plain, covering it with sand and silt, it could not exceed the height of the banks, amounting in the Mississippi to a mean depth of fifteen feet.* There must, therefore, in order to permit the accumulation of the great thickness of strata which exists between the different beds of coal in the more northern districts, have been a successive depression of the land as accumulation progressed. Near the course of the river through the delta the greatest amount of accumulation would occur, becoming lessened and the sediment being finer, as the distance increased, whilst at its extreme limits there would remain only the finest particles of mud. This has been the case in the Coalbrook Dale district, situated in the depressed and filled up site of the commencement of one of the minor tributaries of a large valley or system of valleys, situated on the northern slope of the division of the watershed which separated it from a similar area to the south.

Whether or not this is the correct explanation of the formation of the Carboniferous rocks of the northwest of England, the fact is evident that subsidence of the land progressed simultaneously with the accumulation. Every seam of coal represents the surface of a plain or delta, situated but little above the sea-level, each representing the product of vegetable growth which had flourished for a prolonged period of time; every considerable accumulation between each bed indicates subsidence of the land. This depression is shown to have been in accordance with the amount of accumulation, occurring in some places to an enormous extent in each of the several divisions of the Carboniferous system; whilst in others, as in that of Coalbrook Dale, in each of them it has been small. Nor is the simultaneous occurrence of

* Sir Charles Lyell.

accumulation and subsidence by any means peculiar to the Carboniferous rocks, but can be proved to be coincident during all geological time—from the Laurentian rocks of Canada to the deltas now forming at the mouths of large rivers. Its occurrence is proved wherever in lower beds there are data to determine at the period of their deposition the near proximity to the horizon of the then sea-level or of shallow water, and the subsequent deposition of strata upon them.

Such a simultaneous occurrence of these phenomena during every age and through all time, can only be regarded as the result of cause and effect: that the one is dependent upon the other. Depression may *permit*, but cannot *cause* accumulation. In the instances which have been under consideration the materials have been derived, not from the neighbourhood, but from distant sources, whilst the accumulated weight of the sediments deposited in seas, bays, and deltas is, by the pressure exerted on the crust of the earth, an adequate cause for the occurrence of the depression; the amount of subsidence being greater or less, in accordance with that of the accumulation.

JANUARY 11TH, 1876.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following communications were read:—

A FEW NOTES ON THE PHYSICAL GEOLOGY OF THE SHILLONG PLATEAU, NORTH-EASTERN BENGAL.

BY ALFRED MORGAN.

ON THE ROCKS OF NEW YORK ISLAND AND THEIR RELATION TO THE GEOLOGY OF THE MIDDLE STATES.

BY D. S. MARTIN, A.M.

Prof. of Geology and Nat. Hist. Rutger's Female College, U.S.

(READ BY THE HONORARY SECRETARY.)

ABSTRACT.

"THE rock of which the Island of New York is composed is almost exclusively of what may be termed a gneissoid schist. It is rarely a true gneiss, its general character being that of a coarse-grained mica-schist, traversed here and there by heavy veins of felspar or quartz. The dip is extremely various, the beds being thrown into many folds and arches, often within short distances. The strike, however, is remarkably uniform, having a general course from N.N.E. to S.S.W. It is this uniform strike that determines the whole form of the island, as a long narrow tongue, cut through at its upper end, and so separated from the main land, merely by the Harlem River and Spuyten Dugvel Creek.

"At this point it may be proper to observe the important fact that this ridge, upon which the city of New York stands, is part of a range of crystalline rocks which runs rudely parallel to the Atlantic coast-line for seven hundred miles; and which, though not conspicuous geographically, has yet a great geological interest that has not been duly recognised. This ridge presents, throughout much if not all of its length, a great uniformity of mineralogical and lithological characters, and an equal distinctness from those of the Blue Ridge, with which it has sometimes been confounded.

"North and east of New York this crystalline belt merges into the wide and complicated metamorphic regions of New England; and its distinctness is therefore obscured. By some of its mineralogical features, however, it can be traced with more or less definiteness, through western New England and even north of Vermont, beyond the Canada line. South of New York its course is perfectly clear. Immediately below the city the ridge sinks beneath the general level of the country, and is covered by Mesozoic rocks, until it rises to the surface at Trenton, New Jersey, sixty miles away. The exposure here covers only a few square miles; and the ridge again becomes covered up, until it rises once more at Philadelphia. This time it forms important hills, beginning with the heights of West Philadelphia and Fairmont, and stretching thence in a broad metamorphic belt over all the south-eastern corner of Pennsylvania, and across the state of Maryland into Virginia."

Professor Martin referred to the importance of the ridge, in a geographical point of view, as having determined the site of nearly all the important towns and cities on the coast of that region, and stated that, "Throughout the Atlantic Middle States it divides the

earlier from the later Mesozoic beds—the Triassic from the Cretaceous. The former rest upon its western flank and dip westward; the latter, together with the Tertiaries that overlie them, rest upon its eastern or seaward flank and dip eastward. So definite is this arrangement that it may safely be said that a proper understanding of the relations of this ridge is the key to the Mesozoic geology of the whole region referred to."

The author minutely described the petrological and lithological characters of this great metamorphic belt, which distinguish it from the Blue Ridge more to the westward; and remarked that – "The indication afforded by the facts above stated, when regarded in their general bearings, is to the effect that the whole range of the Atlantic (or Montalban) gneiss has undergone, at some period, what may be termed a secondary metamorphism." "The period of this alteration could scarcely be any other than at or shortly before the close of the Triassic—when the beds of that age, which rest upon and against this range, received a dip which can only be explained with any clearness by supposing an elevation of the gneissic ridge."

Prof. Martin concluded by stating that Prof. Hitchcock agreed with him with regard to both the mineralogical and lithological views advanced in his paper.

THE FORMBY AND LEASOWE MARINE BEDS, AS SHOWN IN A SECTION NEAR FRESHFIELD.

By T. Mellard Reade, C.E., F.G.S.

At a point in North Moss Lane, 5 furlongs S. by E. of Formby Hall, and 1 mile 5 furlongs in a direct line E.

of Freshfield Station, excavations are being carried out by the Patent Fuel Company. These excavations have disclosed the following section:—

	Ft. In.
1. Blown Sand	3·0
2. Peat, containing stools of trees *in situ* at various horizons, beginning at the Clay below, also, skull of horse, and many other bones.....	8·0
3. Fine Blue Clay	3·0
4. Thin bed of Peat	0·2
5. Blue Clay, sandier than No. 3, containing at the base	6·0
6. Shell Bed, containing *Cardium edule, Scrobicularia piperata, Tellina tenuis, Natica Monilifera.*	
7. Bore hole in Blue Clay, not bottomed	10·0
Total about.....	30·2

The following statement occurs in my "Post-Glacial Geology of Lancashire and Cheshire," p. 23:—"In a well at Martin's Farm, Hightown (section 18, plate 4), at 20 feet deep, a bed of marine shells occurred, and *I have no doubt more would be found in other places, did the excavations extend deeper than they usually do.*" The section just described is a remarkable confirmation of this prediction; and situated as the locality is, nearly half way between the excavations at Hightown and those at Birkdale—where marine shells were also found by me in the "Scotch" under the peat—as well as being over 2 miles inland of high-water mark, must, I think, finally settle the question of the Marine origin of these important deposits, showing also that a microscopic determination of these beds, where no mollusca had been discovered at that time, was a reliable one.

For any one who wishes to study, to my mind, the most interesting of local deposits—viz., those from the Glacial era up to the present time—there is now every opportunity, as I have presented to the Liverpool Museum a complete series of specimens, and have arranged them in a way to be readily understood by the aid of my original paper on the subject. I trust shortly that the accompanying maps and sections will also be hung up near the cases to further elucidate the subject. Since that communication was made to the Society, the bones of a *Bos longifrons* and a very pretty skull and horns of a goat have been taken out of Mr. Sawyer's clay pit at Formby (No. 4 on map), and these also are deposited in the Museum. In a gulley in the Canada Docks Extension, two fine skulls of the horse were found and presented to the Museum, by the Engineer, Mr. Lyster. A very fine pair of horns of the red deer were also found in the excavations for the north wall at the Rimrose. It is difficult to determine the ages of these remains: they most likely are later than the Formby Beds, and correspond with the overlying silts. It is interesting, however, to find these records of a former elevation of the land, in the gulleys near low-water mark, so general around our coasts.

FEBRUARY 8TH, 1876.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following communications were read:—

DESCRIPTION OF VALLEY SECTIONS AT LLANDUDNO.

BY HUGH F. HALL, F.G.S.

RECORDS OF GLACIAL STRIÆ IN DENBIGHSHIRE, FLINTSHIRE, AND ANGLESEA.

BY GEORGE H. MORTON, F.G.S.

DURING the last few years I have observed the following localities presenting Glacial Striæ in Denbighshire, Flintshire, and Anglesea. Some of them may have been noticed before, especially in Anglesea; but they all seem to deserve a permanent record, particularly those in the neighbourhood of Llangollen.

LLANYMYNECH.

In October, 1873, I discovered a striated area on the south of Llanymynech Hill, near the top, and close to the face of the quarry. Several yards were exposed, the Carboniferous Limestone presenting an uneven surface, but entirely covered with striæ in the direction E.N.E. and W.S.W. The elevation above the sea is somewhere about 600 feet. Last year, 1875, I found another exposed surface of striated limestone, also near the hill-top, a few hundred yards to the N.E., perhaps 30 square yards. The surface drift, a few feet in thickness, had been removed along the edge of the quarry and the limestone presented the most

interesting area I have seen, so clear and distinct were the striæ running N.E. and S.W. Being a larger area and on a flatter part of the hill, the direction indicated is probably more likely to represent the general course of the ice than the former one, which is just under the highest eminence.

Llangollen.

At Llangollen I found, at the upper edge of the most eastern quarry under Pen-y-Caer, the Carboniferous Limestone to be striated over between two and three square yards. The direction is E. and W., or a few degrees N. of W.

I also found ice marks on the Silurian rock in the valley in front of the entrance to Trevor Hall. Possibly the rock may not be in situ, but a large Boulder partly covered up. However, the direction of the striæ is E. and W., coincident with the valley, which tends to show that it is a rock exposure and not a detached block.

Since this paper was read I have discovered very distinct Glacial striæ, near the highest part of the ridge Pen-y-Caer, just two miles nearly due west from Llangollen. The ridge consists of "Cefn-y-Fedw Sandstone"—Millstone Grit—the highest elevation, close to Whalley's Tower, being 1,280 feet above the sea-level. The striæ occur close to the edge of the precipitous cliff at several spots, and from 40 to 90 feet from the highest part of the ridge as it gradually descends to the south-east towards Trevor Hall. The direction of the striæ is exactly E. and W., just the same as in the valley below, and the elevation fully 1,200 feet above the sea.

Holywell.

Mr. George W. Shrubsole, F.G.S., of Chester, has recently informed me of a Glacial area or striated surface

near to Pen-y-ball, Halkin Mountain. It was discovered on baring the surface of the rock for quarrying. The direction of the striæ is N.E. and S.W., and the altitude 900 feet above the sea.

Anglesea.

In the Carboniferous Limestone to the north of Pentraeth, in Anglesea, there is a thick bed of coarse grit cropping out from about the middle of the formation. It is shown in the quarries which are now worked to be at the least 15 feet thick. The stone is obtained in large blocks and roughly formed into millstones, which are exported to Iceland. At the edge of the quarries at Penrallt, about three miles N.W. from Pentraeth, I observed the surface to be perfectly level and strongly marked with distinct striæ N.E. and S.W., the rock being very hard, resembling typical Millstone Grit, and the striæ very sharp and not likely to be defaced for a long time.

Nearly 2 miles to the N., at a place called Tyddynbach, where the road diverges, I discovered another similar area of the same rock, presenting distinct striæ on a worn down surface in the same direction N.E. and S.W. Part of the area occurs in a field at the side of a cottage, but it extends across the road which runs over the bare rock; and it is very remarkable that the passage of cart wheels and the traffic along the road have not effaced the striæ, so hard is the gritty rock.

Three-quarters of a mile to the N.W. near Penrhoslligwy, on the south side, but close to the River Lligwy, there is another striated area. The rock there is a coarse hard grit which is quarried. It crops out below the lowest beds of Carboniferous Limestone, and is

coloured as "Yellow Sandstone" on the survey map. There is a fine surface exposed, striated in a direction N.E. and S.W., as in the former localities.

On the south side of Lligwy Bay there occurs one of the most interesting sections of the Lower Carboniferous strata in N. Wales. But in addition to the stratigraphical interest of the section, the evidence of ice action on the surface is very remarkable. The low cliffs are contorted in such a manner as to indicate a crumpling by the lateral pressure of ice, as shown in the diagram. Below the contorted strata there are three beds of limestone, perfectly horizontal, and uninfluenced by the force which exerted the pressure on the higher beds. Below these horizontal beds, on the sea shore in front of the outcrop, the surface of a lower stratum of limestone extends for several yards, and its surface is striated in the usual direction N.E. and S.W. The waves of every high tide cover the striated surface, and must have done so for years, and still the striæ seem just as fresh as on the road, where carts pass daily over it, or as in the other localities which have been exposed to the weather for years in succession.

All these ice-marked areas seem to be very permanent, and the flat surfaces offer so little resistance to aqueous action, that they retain the sharp striæ and grooves for a long time before they are obliterated.

MARCH 14TH, 1876.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following communications were read:—

LIST OF WORKS ON THE GEOLOGY, MINERALOGY, AND PALÆONTOLOGY OF CHESHIRE.

BY WILLIAM WHITAKER, B.A., F.G.S.,

Of the Geological Survey of England, Editor of the "Geological Record."

In this List, as in those already published, a chronological arrangement has been adopted, ending with the year 1873, after which date the "Geological Record" supplies fuller information.

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1. Leigh, C. Natural History of Lancashire, Cheshire, and the Peak in Derbyshire, &c. *Fol. Oxon.* ? another Edition in 1700.

1669.

2. Jackson, Dr. W. Some Inquiries concerning the Salt-Springs and the Way of Salt-making at Nantwich in Cheshire. Answered. *Phil. Trans.*, vol. iv, No. 53, p. 1,060.

1670.

3. Martindale, A. Extracts of two letters from Rotherton in Cheshire, concerning the Discovery of a Rock of Natural Salt in that Country. *Phil. Trans.*, vol. v, No. 66, p. 2,015.

1684.

4. Lister, Dr. M. Certain Observations of the Midland Salt-Springs of Worcester-shire, Stafford-shire and Cheshire. *Phil. Trans.*, vol. xiv, No. 156, p. 489.

1691.

5. Ray, J. Collection of English Words not generally used, with Account of the Making of Salt at Nantwych in Cheshire, &c. *Ed.* 2, 12*mo.*

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6. Short, Dr. T. An Essay Towards A Natural, Experimental, and Medicinal History of the Principle Mineral Waters of . . . . . Cheshire, &c. 4*to. Sheffield.*

1781.

7. Jars, M. G. Voyages Metallurgiques, *tome* 3. (Cheshire, p. 332). 4*to. Paris.*

1795.

8. Aikin, J. Description of the Country from thirty to forty miles round Manchester. 4*to.*

1809.

9. Farey, J. Observations on a late Paper by Dr. W. Richardson, respecting the basaltic District in the North of Ireland, and on the Geological Facts thence deducible; in conjunction with others observable in Derbyshire and other English Counties . . . . &c. *Phil. Mag.*, vol. xxxiii, p. 257.

1810.

10. Farey, J. A List of about Five Hundred Collieries in and near to Derbyshire. *Phil. Mag.*, vol. xxxv, p. 431.

1811.

11. Bakewell, R. [Description of Alderley Edge, in Cheshire.] *Monthly Mag.*, vol. xxxi, No. 209, p. 7.

12. Farey, J. A List of about 280 Mines of Lead,—some with Zinc, Manganese, Copper, Iron, Fluor, Barytes, &c., in and near to Derbyshire. *Phil. Mag.*, vol. xxxvii, p. 106.

13. Holland, A. A Sketch of the natural History of the Cheshire Rock-Salt District. *Trans. Geol. Soc.*, vol. i, p. 38.

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14. Aikin, A. Notice on a Green waxy Substance found in the alluvial soil near Stockport, in Cheshire. *Trans. Geol. Soc.*, vol. iv, p. 445.

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17. Sedgwick, Rev. Prof. A. On the Origin of Alluvial and Diluvial Formations. (Cheshire, p. 23). *Ann. of Phil.*, Ser. 2, vol. x, p. 18.

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18. Hibbert, Dr. S. On some Remarkable Concretions which are found in the Sandstone of Kerridge in Cheshire. *Edin. Journ. of Sci.*, vol. iv, p. 138.

1828.

19. Stevenson, R. Remarks upon the Wasting Effects of the Sea on the shore of Cheshire, between the rivers Mersey and Dee. *Edin. New Phil. Journ.*, vol. iv, p. 386.

1829.

20. Brayley, E. W. On the Existence of Salts of Potash in Brine-Springs and in Rock-Salt. *Phil. Mag.*, Ser. 2, vol. v, p. 411.

21. Nicol, W. On the cavities containing Fluids in Rock-Salt. *Edin. New Phil. Journ.*, vol. vii, p. 111.

1830.

22. Daubeny, Dr. C. Memoir on the occurrence of Iodine and Bromine in certain Mineral Waters of South Britain. (Cheshire, pp. 229, 230). *Phil. Trans.*, vol. cxx, p. 223.

23. Oeynhausen, C. von, and H. von Dechen. [On Rock Salt in England.] *Karsten's Archiv.* 1, i, p. 56.

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24. Hall, E. A Mineralogical and Geological Map of the Coal Field of Lancashire, with parts of . . . Cheshire . . . (an inch to a mile). 2 other Editions.

1833.

25. Trimmer, J. Discovery of marine shells of existing species on the left bank of the river Mersey, and above the level of high-water mark. *Proc. Geol. Soc.*, vol. i, p. 419.

1835.

26. Egerton, Sir P. G. On a Bed of Gravel containing Marine Shells of recent species, at "The Willington," in Cheshire. *Proc. Geol. Soc.*, vol. ii, p. 189.

27. Murchison [Sir] R. I. On an outlying basin of Lias on the borders of Salop and Cheshire, &c. *Ibid.*, p. 114.

28. ——— The Gravel and Alluvia of S. Wales and Siluria as distinguished from a northern drift covering Lancashire, Cheshire, &c. . . . *Ibid.*, p. 230.

1836.

29. Egerton, Sir P. De M. G. A notice on the occurrence of marine shells in a bed of gravel at Narley Bank, Cheshire. *Proc. Geol. Soc.*, vol, ii, p. 415.

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30. Anon. Cheshire. "Geological Character." *Penny Cyclopædia*, vol. vii, p. 43. (*Fol. Lond.*)

31. Tooke, A. W. The Mineral Topography of Great Britain. (Cheshire, p. 40). *Mining Review*, No. 9, p. 39.

1838.

32. Anon. (Liverpool Natural History Society). An account of Footsteps of the Chirotherium, and other unknown animals lately discovered in the quarries of Storeton Hill, in the peninsula of Wirrall, between the Mersey and the Dee. . . . illustrated with drawings by J. Cunningham. *Proc. Geol. Soc.*, vol. iii, p. 12.

33. Denham, Capt. On the Tidal Capacity of the Mersey Estuary—the Proportion of Silt held in solution . . . the Excess of Deposit upon each Reflux, and the consequent Effect . . . *Rep. Brit. Assoc. for* 1837, *Trans. of Sections*, p. 85.

34. Egerton, Sir P. De M. G. On two Casts in Sandstone of the impressions of the Hind Foot of a gigantic Chirotherium, from the New Red Sandstone of Cheshire. *Proc. Geol. Soc.*, vol. iii, p. 14.

35. Trimmer, J. On the Diluvial or Northern Drift of the Eastern and Western Sides of the Cambrian Chain, and on its Connexion with a similar Deposit on the Eastern Side of Ireland. . . . *Journ. Geol. Soc., Dublin*, vol. i, part 4, pp. 286, 335.

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36. Cunningham, J. An Account of Impressions and Casts of Drops of Rain, discovered in the Quarries at Storeton Hill, Cheshire. *Proc. Geol. Soc.*, vol. iii, p. 99.

37. Egerton, Sir P. De M. G., and J. Taylor. Letters on a slab of sandstone, exhibiting footmarks, and supposed to be from the Kelsall quarry. *Ibid.*, p. 100.

38. Grant, Prof. [R. E.] Footmarks of Chirotherium at Stourton Hill. *Mag. Nat. Hist.*, Ser. 2, vol. iii, p. 43.

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185. ——— The Lower Scrobicularia and Lower Cyclas Clays of the Mersey and the Ribble. *Ibid.*, p. 287.

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188. Reade, T. M. Formby and Leasowe Marine Beds, or the so-called "Cyclas Clay." *Geol. Mag.*, vol. x, p. 238.

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OBSERVATIONS ON THE SUB-WEALDEN BORING.

By Charles Potter.

APRIL 11th, 1876.

The President, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following communications were read:—

REMARKS ON THE COPPER LODE AT DYFFRYN ALED.

By William Semmons, F.G.S.

A NOTE ON ITACOLUMYTE, OR FLEXIBLE SANDSTONE.

By Alfred Morgan.

The somewhat fanciful name of Itacolumyte has been given to the Brazilian variety of Flexible Sandstone, which is said in some treatises on gems to be diamondiferous in its nature, though I have not met with any authenticated instance of its being so. Indeed, the only reliable information we possess tends to a decided negative of the assertion. My interest in this remarkable rock was awakened during an investigation of the mineralogy of the precious crystals, those "flowers of the mineral kingdom;" and I found in the "Records of the Geological Survey of India,"* a paper by Mr. H. B. Medlicott, A.M., F.G.S., containing fuller information on the subject than I had hitherto met with. According to Dana, "the Ita-

* Vol. vii., p. 31, Calcutta, 1874.

columyte of Brazil, which is associated with Gold and Topaz," is a micaceous, granular quartz rock, which breaks into slabs like gneiss or mica slate. A similar Flexible Sandstone is found in South Carolina and in the neighbourhood of Delhi. The Indian variety is a modified condition of a massive Quartzite or Metamorphic Sandstone. It contains but few and isolated plates of mica, and is devoid of any schistose (foliated) structure.

The only known habitat in India of the Elastic Sandstone is Kaliana, five miles west from Dadri, a town in the Jheend State, sixty miles nearly due west from Delhi. The hill, which is one of the Trigonometrical Survey Stations, is 1477 feet above the sea, and about 740 feet above the plain. It is one of the many ridges which in this region of the Punjab stretch far into the plains, the alluvial areas between being confluent with the Indo-Gangetic Deposits. These ridges are prolongations of the great Aravali system. The highest part of the ridge overhangs the village of Kaliana. "It is here double crested, the projecting ribs being formed by two strong beds of Ironstone, a quartzite strongly impregnated by massive Specular Iron (black hæmatite) and some Magnetic Iron, strings of pure ore occuring locally in the mass. These bands of ferruginous quartzite are regularly inter-stratified with the mica and hornblende schists; and the earthy, cellular quartzite so largely quarried for millstones is distinctly an intercalated member of the same series, all being nearly vertical. The Elastic Sandstone is only found in patches in this band of millstone quartzite. There is no regular seam of it; the stone-cutters, of whom there is quite a colony at Kaliana, come upon it suddenly when cutting out slabs of the ordinary stone. Often the rock in immediate contact with a nest of the Elastic Sandstone is highly indurated

and quartzose. The stone-cutters declare they sometimes find it in the line of bedding and sometimes in the joints. Their idea of the matter is that it is a mere local peculiarity of the Sandstone rock caused by the percolation of rain water and *miti* (earth) from the surface."

It is probable, as Mr. Medlicott observes, that if the *miti* had been omitted the natives' explanation is the correct one. Superficially examined, the only difference observable is the greater porosity and friability of the flexible stone, as compared with the quartzite. And the peculiar property of flexibility is probably due to the mechanical removal of some thinly permeating cement to which the strong rigidity of the quartzite is due. The stone bends very readily up to a certain point and then comes to an abrupt stop. Mr. F. R. Mallet* found that a slab of the Kaliana stone 24·5″ x 6·7″ x 1·8″, resting on supports 24″ apart, gave a deflection of 0·7″; and that after saturation with the deflection was reduced to 0·65.

The only tenable account of this property of elasticity is that given by Professor Haughton.†

"A most remarkable circumstance sometimes occurs in the formation of these Sandstones, which are not composed of pure particles of quartz, but a clay mixed with them, namely, that the particles of quartz mixed in this clay or paste are permitted a certain amount of motion. If you take an ordinary sandstone, it is like any other rock; and with a lens you can see the separate particles, and that each separate particle is touched on every side by a number of other rounded particles that hold it in its place, and it in turn contributes to hold them in their places, so as to form of the whole a rigid rock like any other. But, occasionally in some rare cases—which, as far as I have any knowledge of them, are confined to

* Op. Cit. † Manual of Geology—Haughton Lecture ii., p. 51.

Brazil, South Carolina, and Delhi—you have a rock composed of particles of sandstones, which are not in contact with each other, but lie in a paste of felspathic clay, which clay permits a certain amount of motion between the particles of the mass."

The flexibility is certainly not attributable to the presence of talc or mica, the rock not having any schistose appearance and the few small plates of mica being very widely separated. It would seem that doubly metamorphosing conditions were concerned in its production—a solidifying process to give tenuity to the earthy paste, and a partial dissolution to remove the rigidity of its first solidification.

I am indebted to the Committee of the Liverpool Free Public Museum for permission to bring before the Society the beautiful specimen of the Indian variety that was presented to the Museum by Mr. Robert Gladstone. The Museum also contains a specimen of the Brazilian stone which differs considerably in appearance from the Indian specimen, in possessing a finer grain and a greyish, mottled, colouring. The question—what is the true matrix of the Diamond? yet remains unanswered, but all that we know of Itacolumyte dispels the idea that they are in any wise associated.

THE CARBONIFEROUS LIMESTONE AND MILLSTONE GRIT OF NORTH WALES,

By George H. Morton, F.G.S.

LIST OF WORKS RELATING TO THE SUBJECT.

The author does not pretend to have made a complete List, and will therefore be glad to hear of any Papers that are unnoticed.

1778.

Pennant, T.—"Travels in North Wales."

1816.

Clark, E. D., LL.D., F.G.S.—"Analysis of One Hundred Parts of Dark Bituminous Limestone, from the Parish of Whiteford, in Flintshire, North Wales."—*Trans. Geol. Soc.*, Ser. 1, Vol. iv., p. 430.

1819.

Greenough, G. B., F.G.S.—Geological Map of England and Wales.

1822.

Conybeare, Rev. W. D., F.G.S., and Phillips, William, F.L.S.—"Outlines of the Geology of England and Wales."

1829.

Yates, Rev. James, M.A., F.G.S.—"Observations on the Structure of the Border Country of Salop and North Wales, and of some Detached Groups of Transition Rocks in the Midland Counties." (*Read* 1825.)—*Trans. Geol. Soc.*, Ser. 2, Vol. ii., p. 237.

1839.

MURCHISON, Sir R. I., F.R.S., F.G.S.—"The Silurian System."

1841.

BOWMAN, J. E., F.L.S.—"Notes on a Small Patch of Silurian Rocks to the West of Abergele, on the Northern Coast of Denbighshire." (*Read* 1838.)—*Trans. Geol. Soc.*, Ser. 2, Vol. vi., p. 195. An Abstract in *Proc. Geol. Soc.*, Vol. ii., p. 666.

1845–57.

GEOLOGICAL SURVEY of the United Kingdom; Maps and Sections of North Wales. Quar. Sheets, 74 N.E. and S.E. Horizontal Sections, 39 and 44. Vertical Section, 24.

1846.

SEDGWICK, Rev. Prof. A., F.G.S.—"Outline of Geological Structure of North Wales." (*Read* 1843.)—*Proc. Geol. Soc.*, Vol. iv., p. 212.

———— "On the Older Palæozoic (*Protozoic*) Rocks of North Wales." (*Read* 1843.)—*Proc. Geol. Soc.*, Vol. iv., p. 251, and *Jour. Geol. Soc.*, Vol. i., p. 5.

SHARP, D., F.G.S.—"Contributions to the Geology of North Wales." (*Read* 1844.)—*Jour. Geol. Soc.*, Vol. ii., p. 288.

1853.

HAUGHTON, Rev. Prof. S., A.M., F.G.S.—"On the Newer Palæozoic Rocks which border the Menai Straits in Carnarvonshire." (*Read* 1853.) *Jour. Geol. Soc. of Dublin*, Vol. vi., p. 1.

1857.

MOISSENIT, M. L., Ingenieur des Mines.—"Mémoir sur le Gisement du Minerai de Plomb, dans le Calcaire Carbonifére du Flintshire."

1862.

DUCKWORTH, H., F.G.S.—"Report of the Excursion made by the Society to Holywell, July, 1861."—*Proc. L'pool Geol. Soc.*, Vol. i., Sess. 3.

1863.

DAVIDSON, T., F.G.S.—"Carboniferous Brachiopoda." —*British Fossil Brachiopoda*, Vol. iii.

1864.

DAVIES, D. C.—"Geology and Botany of the District" in *Roberts' Llangollen Guide*, p. 53.

1865.

DAVIES, D. C.—"On the Discovery of Fossils in the Millstone Grit near Oswestry." (*Read* 1860).—*Rep. Oswestry and Welshpool Nat. Field Club*, p. 41.

———— "The Mountain Limestone of North Wales." (*Read* 1861).—*Rep. Oswestry and Welshpool Nat. Field Club*, p. 50.

PROSSER, W., F.G.S.—"The Fossiliferous Character of the Millstone Grit at Sweeney, near Oswestry, Shropshire."—*Geol. Mag.*, Vol. ii., p. 107.

JUKES, J. B., Prof., F.G.S.—"Former Extension of the Coal Measures."—*Geol. Mag.*, Vol. ii., p. 135.

MAW, G., F.G.S.—"On some Deposits of Chert, White Sand, and White Clay in the Neighbourhood of Llandudno, North Wales."—*Geol. Mag.*, Vol. ii., p. 200.

DAVIES, D.C.—"The Outlier of Carboniferous Limestone near Corwen, North Wales."—*Geol. Mag.*, Vol. ii., p. 283.

JUKES, J.B., Prof., F.G.S.—"The Outlier of Carboniferous Limestone near Corwen."—*Geol. Mag.*, Vol. ii., p. 326.

MAW, G., F.G.S.—"Permian Strata of the Vale of Clwyd."—*Geol. Mag.*, Vol. ii., pp. 380, 523.

——— "Letter on a White Sand Deposit at Talargoch Mine, near Prestatyn, Flintshire, North Wales."—*Geol. Mag.*, Vol. ii., p. 428.

DAVIES, D. C.—"Denudation, Unconformability, and the Vale of Clwyd."—*Geol. Mag.*, Vol. ii., p. 476.

RICKETTS, C., M.D., F.G.S.—"On the Outlier of Carboniferous Limestone near Corwen, North Wales." *Proc. L'pool Geol. Soc.*, Vol. i., Sess. 8.

1866.

RAMSAY, A. C., Prof., LL.D., F.G.S.—"The Geology of North Wales."—*Mem. of Geol. Surv. of Gt. Brit.*, Vol. iii.

1867.

GREEN, A. H., M.A., F.G.S.—"On the Lower Carboniferous Rocks of North Wales."—*Geol. Mag.*, Vol. iv., p. 11.

DAVIES, D. C.—"The Lower Carboniferous Rocks of North Wales."—*Geol. Mag.*, Vol. iv., p. 92.

BOSTOCK, R.—"The probable source of Holywell Spring."—*Proc. L'pool Geol. Soc.*, Vol. i., Sess. 9.

1869.

MORTON, G. H., F.G.S.—"Palæontological Observations on the Carboniferous Limestone in Flintshire."—*Proc. L'pool Geol. Soc.*, Vol. i., Sess. 10.

1870.

DAVIES, D. C.—"On the Millstone Grit of the North Wales Border."—*Geol. Mag.*, Vol. vii., pp. 68 and 122.

AITKEN, J., F.G.S.—"The Grit-rocks of the Eastern Border of North Wales."—*Geol. Mag.*, Vol. vii., p. 263.

MORTON, G. H., F.G.S.—"The Mountain Limestone of Flintshire and part of Denbighshire."—*Rep. Brit. Assoc.* for 1870, p. 82.

1873.

DAVIES, D. C., F.G.S.—"On the overlapping of several Geological Formations on the North Wales Border."—*Proc. Geol. Assoc.*, Vol. ii., p. 299.

——— "On Coal Seams in the Permian at Ifton, Shropshire."—*Proc. Gecl. Assoc.*, Vol. iii., p. 138.

MORTON, G. H., F.G.S.—"The Strata below the Trias in the Country around Liverpool, and the probability of Coal occurring at a moderate depth."—*Proc. Lit. & Phil. Soc., L'pool*, Vol. xxvii., p. 157.

1876.

DAVIES, D. C., F.G.S.— "On some causes which have helped to shape the land on the North Wales Border."—*Proc. Geol. Assoc.*, Vol. iv., p. 340.

LLANGOLLEN.

REVIEW OF WORKS RELATING TO THE CARBONIFEROUS LIMESTONE AND MILLSTONE GRIT OF LLANGOLLEN.

STRATA of the Carboniferous Period in North Wales are most fully developed in the country between Minera and Llanymynech, and the grandest section of the Carboniferous Limestone in the Principality may be seen from the summit of Castell Dinas Bran, close to the town of Llangollen. A section of such interest naturally attracted the attention of geologists many years ago; and so early as 1778 Thomas Pennant, in his "Travels in North Wales," after accurately describing the succession of the Carboniferous Series in the neighbourhood of Mold, mentions the "Glisseg rocks" and "Craig Arthur" as part of the great ridge of limestone he describes.

In the "Outlines of the Geology of England and Wales," 1822, by Conybeare and Phillips, under the heads of "Carboniferous Limestone of North Wales,"

and "Flintshire," there is a notice of the Eglwyseg rocks and the district to the south of Llangollen. A few years later, in the *Transactions of the Geological Society*, 2nd Ser., vol. ii., for 1829, the following paper occurs:— "Observations on the Structure of the Border Country of Salop and North Wales; and of some detached Groups of Transition Rocks in the Midland Counties." By the Rev. J. Yates, M.A., F.G.S. This paper contains a graphic description of the Eglwyseg rocks. The author states:—

"At the distance of about two miles to the N.E. (of Llangollen) is presented the perpendicular face of the rocks of Edlw-y-seg. These are part of the edge of the great basin of limestone, containing the coal formation of North Wales. Their direction is generally from east to west, but in a waving course, and through a tract of many miles in length. A steep talus of *débris* covers about two-thirds of their height; and above this their face rises almost perpendicularly, presenting a remarkable specimen of regular stratification, and a striking contrast to the forms of the slate mountains in their vicinity. The divisions of the strata of limestone are rendered conspicuous at a distance by beds of black bituminous shale, which lie between them. This shale is for the most part perfectly soft and friable; it is, however, frequently indurated by the addition of calcareous matter, and thus passes into fœtid limestone. It is also sometimes mixed with a large proportion of sand, and then resembles very much the mud deposited in the estuaries of the Dee and Mersey.

"These cliffs contain various shells and corals, usually considered as belonging to the Mountain Limestone of England. In the case of shells occurring in the limestone beds, the matter of the shells is generally

removed, only casts remaining, or newer depositions of calcareous spar in place of the original substance. But in the beds of shale the testaceous matter seems to be preserved, with very little alteration in its texture or composition. In a formation of so great antiquity in the geological history of the globe, this circumstance appears not a little curious and interesting. The softness of the shale in which they are imbedded, also contributes to render these specimens of fossil shells remarkably perfect, the muscular impressions and interior structure of the larger *Terebratulæ* being exhibited with great distinctness." The author also refers to "the lively red colour of the ploughed fields, and the rounded masses of red conglomerate scattered among the *débris* of the limestone" in front of the Eglwyseg range.

The Millstone Grit, as it occurs to the west of Oswestry, particularly in the neighbourhood of the Race Course and Mynydd Myfyr, is minutely described. The lowest beds immediately above the Carboniferous Limestone are shown to be conglomeratic, succeeded by red sandstones resembling the New Red Sandstone of Lancashire, Cheshire and Shropshire; and these are overlaid by other sandstones, containing *entrochi*, and finally by hornstone strata passing into flint. The author evidently examined the district thoroughly, and he has given one of the best descriptions that we have of the strata of the Lower Carboniferous Series in the neighbourhood of Oswestry.

In 1839, Sir R. I. Murchison, F.R.S., in the "Silurian System," described the same strata a little to the south-east, at Treflach Hall, in the vicinity of Sweeney, where Mr. D. C. Davies has since obtained a large collection of fossils from sandstone strata, about which several recent communications have appeared.

The next work in the order of date which contains any description of the Lower Carboniferous rocks in the country around Llangollen, is a paper entitled "Outline of Geological Structure of North Wales," by the Rev. A. Sedgwick, F.G.S. *Proc. Geol. Soc.*, vol. iv., 1846. The paper principally refers to the Silurian; but the Carboniferous Group of Denbighshire is noticed. The author refers to the red sandstones and conglomerates at the base of the Mountain Limestone in the county; the outliers of limestone at Corwen and Caergwrle, and other subjects connected with the Geology of North Wales. There is another paper by the same author, "On the Older Palæozoic (*Protozoic*) Rocks of North Wales," *Proc. Geol. Soc.*, vol. iv, 1846, in which he gives a description of those stratified rocks in the northern counties of the Principality, which are of anterior age to the Carboniferous Limestone. At page 263, there is a section showing the Eglwyseg rocks resting unconformably on the folded Upper Silurian flagstones of the Dee. There is a map of North Wales appended, which shows the Carboniferous Limestone of Denbighshire and Flintshire, including its extension south to Llanymynech, the patches in the Vale of Clwyd, and the outlier at Hafod, near Corwen.

"Contributions to the Geology of North Wales," by D. Sharp, F.G.S., *Jour. Geol. Soc.*, vol. ii., 1846, is another paper wherein mention is made of the Eglwyseg rocks, and the author states that "the Ludlow rocks of Llangollen dip at a low angle, and pass conformably below the Mountain Limestone of the Eglwyseg Crags." It has been since determined that these Silurian Strata are of Wenlock age, and Prof. Sedgwick had previously shown that the Carboniferous Limestone rests unconformably upon them.

The country around Llangollen was surveyed by the officers of the Geological Survey about 1845, and the "Quar. Sheets," 74, N.E. and S.E., containing it, were published soon afterwards. The "Horizontal Sections," Nos. 39 and 44 and the "Vertical Section" No. 24 appeared about the same time. The geologists engaged on that survey were Professors Ramsay, Jukes, Forbes, Geikie, and Messrs. Aveline, and Williams.* This valuable map and the sections show the area and position of the Carboniferous Limestone and Millstone Grit in relation to the formations with which they are associated. However, on minutely examining the map, it appears that the boundary line between the Carboniferous Limestone and Millstone Grit does not continue on the same Geological horizon; there having evidently been a difficulty in dividing the two formations. The discrepancy between the two horizontal sections is still more remarkable, considering that they both traverse the Eglwyseg rocks within half-a-mile from each other.

The Millstone Grit of North Wales does not of necessity represent exactly the same formation in Derbyshire and Yorkshire. It probably includes both the Millstone Grit and the Yoredale, or Upper Carboniferous Shale of those counties; and there is no reason for supposing that the deposition of the Carboniferous Limestone terminated at precisely the same time in districts nearly one hundred miles apart.

In 1864, Mr. D. C. Davies' "Geology and Botany of the District" of Llangollen, appeared in *Roberts' Llangollen Guide;* and in 1865 a paper by the same author (read 1861), was published by the Oswestry and Welshpool Naturalists' Field Club, entitled "The

* Geikie's "Life of Forbes," page 444.

Mountain Limestone of North Wales." It is the first communication entirely devoted to the subject, and is a description of the Carboniferous Limestone of Denbighshire and Flintshire. There are very few details given respecting any of the numerous localities referred to by the author, who rather gives the general results of his observations over the whole area described.

Mr. Davies describes three main divisions of the Mountain Limestone of North Wales, as follows:— "In ascending order, there is, first, a series of beds of pale-coloured stone, extensively quarried along the belt for fluxing purposes, interleaved with five principal layers of red marl. Above there is a succession of beds, varying from a bituminous texture through a sandy limestone impregnated with copper, to a hard compact grey limestone; and, lastly, an alternation of thin layers of limestone, with dark blue and black deposits of fossiliferous shale, and the whole series attaining a maximum thickness of about 400 feet." Although this is a general description of the formation as represented in North Wales, it seems to apply particularly to the south-east of the Eglwyseg ridge, and to the country between Llanymynech and Oswestry.

With regard to Llangollen, Mr. Davies states that *Productus hemisphericus* (*comoides*) occurs in the lower limestone, and above is *P. cora*, which is abundant in the Trevor Quarries, near Llangollen. These he considers characteristic of the lower beds, and next to them *P. semireticulatus*. The *Terebratulæ*, he says, are well represented in the lower beds, and *Sanguinolites clava* attains to a great size in the middle beds near Llangollen. Many other fossils are mentioned, though it is not clear that he refers to Llangollen as their locality, though it seems to be so; indeed, he says that

the beautiful corals *Lonsdaleia, Sarcinula Phillipsi.* and two species of *Stylaxis* attain to luxuriant growth on the Eglwyseg ridge. At the conclusion of the paper the author promises a list of the fossils collected from the Mountain Limestone, but unfortunately no such list has appeared. Both the communications are written in a popular form, without the exactness which a purely scientific description would have rendered necessary.

A paper by Mr. D. C. Davies appeared in 1865, "On the Discovery of Fossils in the Millstone Grit near Oswestry," in the *Rep. Oswestry and Welshpool Nat. Field Club*, five years after the communication had been read. Another paper appeared in the *Geological Magazine* for 1865, vol. ii, on "The Fossiliferous character of the Millstone Grit at Sweeney, near Oswestry, Shropshire," by W. Prosser, F.G.S. The author gives a section from Murchison's "Silurian System" of the Carboniferous strata, near Oswestry, which includes the Millstone Grit, and gives Mr. D. C. Davies the credit of having been one of the first to describe the fossiliferous character of the formation. He also describes the strata around Sweeney, the typical locality, and concludes with a list of sixteen fossils that he had found in the neighbourhood.

In 1866, the 3rd vol. of the *Memoirs of the Geological Survey of Great Britain* was published, and devoted to "The Geology of North Wales," by Prof. Ramsay. It contains (at page 226) a paragraph on Llangollen, as follows:—"South-east of the Vale of Clwyd, between the Bala beds of Cyrn-y-brain and the Berwyns, the Wenlock Shale fills a space about six miles broad, consisting of steep-sided round-topped hills, intersected from east to west by the river Dee. Numerous subsidary valleys branch north and south from the river

into the heart of the hills. On the east, between Craig Arthur and Ty-uchaf,* the Old Red Sandstone rests unconformably upon it. From thence to Tan-y-Castell,† a fault passes from Y-fron-fawr to the south-east, and throws first the Old Red Sandstone, and then the Carboniferous Limestone and Millstone Grit, against the Wenlock Shale above the river Dee, to a point four miles east of Llangollen." No sections exhibiting any of the subdivisions of the Carboniferous Limestone have been published. Those of the Geological Survey (Nos. 39 and 44,) merely show the Carboniferous Limestone and its thickness in relation to the formations with which it is associated; though with a separation of 175 feet of the lower beds, described as the "Yellow Sandstone and Dark Shale," corresponding in position to the Lower Brown Limestone, but no yellow sandstone occurs there.

During 1867 a paper appeared "On the Lower Carboniferous Rocks of North Wales," by Mr. A. H. Green, M.A., F.G.S., in the *Geol. Mag.*, vol. iv., where the author gives the result of a survey of the country to the north-east of Tan-y-Castell. He gives two sections, and, from the lithological characters of the Millstone Grit, considers that the greater part of the formation belongs to the Yoredale series; a conclusion favoured by the presence of a band of earthy limestone and Mountain Limestone fossils associated with a bed of shale 15 feet thick, near Tyfyn-uchaf. The conglomerate above the shale-bed he thinks may represent the Rough Rock, or First Grit of the Millstone Grit Series, and that the lower strata may be Yoredale beds, as they agree very well with the middle division of that formation in North Staffordshire.

* About two miles N. of Llangollen.

† One mile N. of Llangollen.

In 1870 another paper appeared "On the Millstone Grit of the North Wales Border," by Mr. D. C. Davies. *Geol. Mag.*, vol. vii. The author supports the assumption that the Grit rocks of North Wales are Millstone Grit, and adds to the number of species contained in Mr. Prosser's list. The same year Mr. J. Aitken, F.G.S., contributed the following paper on the same subject, to the *Geol. Mag.*, on "The Grit-rocks of the Eastern Border of North Wales." The author supports the Yoredale affinities of the strata, on similar grounds to those arrived at by Mr. Green; and it is important, because both of these writers have been long familiar with the Lower Carboniferous Series of Yorkshire and Lancashire. Mr. Aitken, however, does not appear to have seen the sandstone, shale, and conglomerate at Tyfyn-uchaf, described by Mr. Green.

In 1870 I read a paper before the British Association, and gave a general description of the Carboniferous Limestone of North Wales; but particularly of the formation as developed near Llangollen.

During 1873, Mr. D. C. Davies, F.G.S., read a paper "On the Over-lapping of several Geological formations on the North Wales Border." *Proc. Geol. Assoc.*, vol. ii. There is a Geological map of the district appended to it, showing the formations which occur in that part of North Wales. On this map, Mr. Davies adopts Mr. Green's Yoredale rocks and Millstone Grit. The same year, Mr. Davies read another paper, *Proc. Geol. Assoc.*, vol. iii, "On Coal Seams, in the Permian at Ifton, Shropshire," from which it appears that the strata around Moreton, north-east of Llanymynech, may be Coal Measures or Permian, and not Millstone Grit.

From the numerous contributions that have appeared relating to the Millstone Grit of North Wales, it is

evident that it possesses considerable interest. It is difficult to correlate it with the same formation in Staffordshire, Derbyshire, and Yorkshire; for it has somewhat peculiar lithological characters, and an unusual number of fossil shells and corals indicating the marine conditions under which the strata were deposited. Several sections of the Millstone Grit country have appeared in illustration of the numerous papers referred to; but there is no indication of drawing to an exact scale, with a correct contour of the ground, and the line of country represented is only roughly given.

No list of the fossils of the Carboniferous Limestone of North Wales, or of any restricted area in the Principality, has appeared. The lists of the Millstone Grit fossils, by Messrs. Davies and Prosser, may be considered complete for the Oswestry district; but little or nothing has been done elsewhere.

CARBONIFEROUS LIMESTONE AND MILLSTONE GRIT.

LLANGOLLEN.

CREIGIAU EGLWYSEGLE AND THE TREVOR ROCKS.

One of the grandest and most accessible exposures of the Lower Carboniferous Series in Great Britain occurs near the town of Llangollen. The precipitous and lofty ridge known as Creigiau Eglwysegle, or more commonly as the Eglwyseg rocks, presents the whole of the Carboniferous Limestone in an unbroken series of strata, from the Old Red Sandstone at its base to the Millstone Grit of the Geological Survey at the summit. Almost every bed of limestone is exposed so that the lithological character of the rocks and the fossils they contain can be easily examined. The interstratified beds of concretionary shale, which occur at frequent intervals, are usually obscured by the limestone strata breaking down over their disintegrated edges. This description of the strata refers particularly to the magnificent natural section exposed in the Ty-nant ravine (Frontispiece, Plate 2), between Craig-yr-ogof on the north, and Y-Craig-bensyth on the south side of it; two massive terraced hills, whose summits are about 1350 feet above the level of the sea, and 600 feet above the narrow road at the base. A similar section is presented in Tan-y-Castell ravine (Pl. 1), which is steeper, not being so deeply cut into the rocky ridge, just half-a-mile northwest of the farm house bearing the

This grand exposure of the Carboniferous Limestone is rendered still more interesting by the regular succession of a great thickness of sandstone with interstratified shale, which rises with a bold outline, and forms the mountain mass of Cefn-y-Fedw, above all the terraced sections of the underlying limestone, and probably represents the Yoredale and Millstone Grit formations. The surface of this high ground presents a rounded series of eminences which gradually descend to the east, where the Millstone Grit or Cefn-y-Fedw Sandstone is succeeded in regular sequence by the Coal Measures.

The whole of the strata described is exposed in such a clear series of sections from Cefn-y-Fedw to Fron Deg, south of Minera, that the country under review must be considered as the typical area of the Lower Carboniferous Series in North Wales.

Mr. W. H. Wilson has interested himself in the Geology of the district, and taken large photographs of the typical sections of the Carboniferous Limestone. The Frontispiece, Plate 2, has been reproduced in its original form; but Plates 1 and 3 have been reduced. They afford the means of explaining the contour of the surface, and the subdivisions into which the Carboniferous Limestone is divided, just as if actually on the ground in front of the rocky ridge.

TAN-Y-CASTELL RAVINE.

Plate 1, presents a view of the south-west escarpment of the Eglwyseg ridge and the Tan-y-Castell ravine, taken from the summit of the isolated hill in front—Dinas Bran —777 feet above the River Dee. From this elevation the whole of the Carboniferous Limestone is displayed in one grand natural section along the line of the outcrop of the strata. The highest beds have been denuded from

same name. This ravine is indicated by a wall built along its ascending slope, and which is conspicuous from the summit of Castell Dinas Bran, 1052* feet above the sea. The Ty-nant ravine is just a mile due north of Dinas Bran, and the Tan-y-Castell ravine about half that distance.

Fine sections of the strata are also exposed at the south-east end of the Eglwyseg ridge, at the Trevor rocks, where extensive limestone quarries are worked and the ridge ends, or is rather cut back by the little brook, the R. Erwen of the 1-inch Ordnance Map. At the other side of this brook the worked face of Bronheulog quarry (Pl. 3), exposes about 162 feet of limestone at a lower level, and above it there is a scar of the Upper Grey Limestone, with the Millstone Grit of Garreg Pengruch at a considerable elevation above it. The latter sections are much reduced in thickness by the attenuation of the Carboniferous Limestone to the south-east, and are traversed by two faults, parallel with the boundary fault which throws up the Wenlock Shale; and, consequently do not exhibit the whole of the limestone formation in an unbroken series as in the typical ravines referred to, where no faults occur.

Under these conditions in addition to the terraced escarpment there are two fine natural sections, affording the clearest possible view of all the Carboniferous Limestone strata 1200 and 1025 feet in thickness. Then there are two other sections, where the strata are attenuated, faulted, and so extensively quarried that they can be examined more minutely than in the sections where the rocks have been exposed to atmospheric influences for untold ages.

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* This altitude was courteously communicated by the Ordnance Survey.

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Mr. W. H. Wilson has interested himself in the Geology of the district, and taken large photographs of the typical sections of the Carboniferous Limestone. The Frontispiece, Plate 2, has been reproduced in its original form; but Plates 1 and 3 have been reduced. They afford the means of explaining the contour of the surface, and the subdivisions into which the Carboniferous Limestone is divided, just as if actually on the ground in front of the rocky ridge.

TAN-Y-CASTELL RAVINE.

Plate 1, presents a view of the south-west escarpment of the Eglwyseg ridge and the Tan-y-Castell ravine, taken from the summit of the isolated hill in front—Dinas Bran —777 feet above the River Dee. From this elevation the whole of the Carboniferous Limestone is displayed in one grand natural section along the line of the outcrop of the strata. The highest beds have been denuded from

Plate I.



out in the extreme back ground, where several small quarries expose the strata, and have yielded many species of corals and brachiopoda. Still higher ground succeeds as the Sandy Limestone crops out, but the surface is covered with peaty soil, and scattered blocks of white sandstone lie about until the highest portion of Cefn-y-Fedw is attained, when the Lower Sandstone and Conglomerate occurs, and blocks of the rock project above the peaty soil. The highest bed of Carboniferous Limestone at Tan-y-Castell ravine is about 600 feet above its base, which is assumed to be parallel with the road skirting the ridge. The dip of the strata is 15° N.E. or E.N.E.; and the entire thickness of the limestone about 1025 feet.

TY-NANT RAVINE.

Plate 2—Frontispiece—presents a view taken from near the top of Y-Craig-bensyth, looking north towards Craig-yr-ogof and down into the Ty-nant ravine, presenting the most rugged section of the Carboniferous Limestone in its natural grandeur. The subdivisions into which it is divided present such distinctive characters that they can be recognised at a considerable distance by the great differences of their stratification, and by the manner in which the rocks break up along their respective outcrops. The fields at the bottom of the ravine cover the upper beds of the Old Red Sandstone, and the talus which skirts the lower part of the hill obscures the Lower Brown Limestone, which is quarried in several elevated positions. The massive beds of the Lower White Limestone project boldly forward near the top of the precipice, and the *thick-bed* is the stratum just over the top of the talus. The wide terrace above the Lower White Limestone, previously described, is well defined, and it is

partly covered by débris from the ends of the Upper White Limestone above it. The peculiar manner in which the strata of the latter subdivision break up is well shown along the outcrop in the centre of the foreground. Higher up to the right the Upper Grey Limestone succeeds, with its usual talus of *small* stones, presenting a great contrast to the Upper White Limestone. The highest beds of the Upper Grey Limestone, which are remarkably fossiliferous, are well marked by the light-coloured line in the middle distance; and further on the Sandy Limestone and the Lower Sandstone and Conglomerate succeed on the highest portion of Cefn-y-Fedw. The contrast between the country composed of the Carboniferous Limestone, and that of the Cefn-y-Fedw Sandstone is very remarkable. Over the limestone a short grass covers the surface like a carpet, and patches of ferns occupy the sheltered hollows and recesses; but over the sandstone the ground is soft, dusty, and uneven in summer, and often like peaty mud in winter. The highest part of this heathy waste is encumbered with loose stones, so white from the numerous quartz pebbles they contain, that when seen from a distance, even in summer, the ground seems to be covered with a sprinkling of snow; it is a desert waste where very few travellers care to venture. From this elevated position the surface of the country slopes towards the east, and the strata dip in the same direction. Immediately above the Lower Sandstone and Conglomerate, there are some hard, cream-coloured shales, and these are succeeded by other sandstones and black shales, and finally by the Aqueduct Grit—which resembles typical Millstone Grit. The latter is succeeded by a thick bed of black shale, and the Aqueduct Coal, forming the base of the Coal Measures. The highest bed of the Carboniferous

Limestone at the Ty-nant ravine is about 650 feet from its base, which is assumed to be forty yards east of the main road below. The dip of the strata is 12° E. or E.S.E., and the entire thickness about 1200 feet.

BRON-HEULOG QUARRY.

Plate 3, is a photograph of the large Bron-heulog Quarry, below Pen-y-gloppa,* and much nearer the River Dee than the Trevor quarries, at the south-east end of the Eglwyseg ridge. The Erwen brook runs down the hollow in the centre; and the tramway in the foreground down an incline of 275 feet, then along the front of the quarry, and after passing through a cutting descends another incline of 300 feet to the wharf on the canal bank. The strata which crop out on the left hand belong to the Upper Grey Limestone, and the ridge higher up above the road is the Sandy Limestone, which is well exposed where the road winds round the hill. There is a fault to the left of the large quarry, nearly parallel with the foot-path, and it runs through the slight hollow at the top of the natural scar. This fault throws up the strata on the right (south-east). The scar represents the lower portion of the Upper Grey Limestone, the upper beds of the subdivision having been denuded, and the strata exposed in the quarry belong to the Upper and Lower White Limestone. The boundary fault which throws up the Wenlock Shale is under the field, on the right hand side below the quarry; but there is another parallel fault which runs along the floor of the quarry, and is visible at the south-east end. This latter fault continues along the tramway, and throws up the strata here and in the Trevor quarries in a similar manner. The

* Pen-y-gloppa is the scar of limestone just above Bron-heulog quarry, "392" on the 25-in. Ordnance Map; but the name is not inserted.

Plate III.



top of the limestone scar is nearly 300 feet from the floor of the quarry below; and the strata dip at an angle of 5° N.E. The thickness of the successive beds has been measured; the total amount being 269 feet, and as the section is almost perpendicular, a slight addition necessary for the dip is sufficient to account for the difference. Plate 4 is a ground plan of the faults showing the nature of the dislocation to which the Carboniferous Limestone has been subjected.

In describing the preceding sections as exhibited in Plates 1, 2 and 3, frequent reference was made to the subdivisions into which it is proposed to divide the Carboniferous Limestone and Cefn-y-Fedw Sandstone in the country around Llangollen. The latter formation probably represents both the Yoredale and Millstone Grit, though it does not lithologically resemble either. All the subdivisions succeed each other in regular sequence, and the Coal-measures repose conformably on the Aqueduct Grit, which is the uppermost member of the Cefn-y-Fedw Sandstone.

The following is a Tabular View of the whole of these subdivisions, with the thickness of each, as exhibited along the line of section from the base of the Ty-nant ravine due east to Tyfyn-uchaf, the distance being rather less than three miles.

TABULAR VIEW OF THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE IN THE COUNTRY AROUND LLANGOLLEN.

		FEET.	
Cefn-y-Fedw Sandstone	Aqueduct Grit, or Upper Sandstone and Conglomerate	70	Upper Cefn-y-Fedw, Dee Bridge, or Millstone Grit Series.
	Upper Shale	30	
	Dee Bridge Sandstone	30	
	Lower Shale, with Fire-Clay and Bands of Limestone	18	Middle and Lower Cefn-y-Fedw or Yoredale Series.
	Middle Sandstone	200	
	Cherty Shale	50	
	Lower Sandstone and Conglomerate	250	
	Sandy Limestone	75	
Carboniferous Limestone.	Upper Grey Limestone	300	Upper Carboniferous Limestone.
	,, White ,,	300	
	Lower ,, ,,	120	Lower do.
	,, Brown ,,	480	
		1923	
	Upper Old Red Sandstone	300	

All these subdivisions are founded on lithological differences, and they can each be traced over a considerable area. Both the Carboniferous Limestone and the Cefn-y-Fedw Sandstone contain numerous beds of shale; but the first is essentially a limestone and the second a sand*stone formation.*

OLD RED SANDSTONE.

The upper strata of this formation occur on the west of the Eglwyseg ridge. They crop out from under the Carboniferous Limestone near Craig Arthur, and extend along the bottom of the Ty-nant ravine round to the south-east as far as Tan-y-Castell; though the breadth of the outcrop scarcely exceeds a quarter of a mile, even where the strata are most fully developed. The extent of the area is for the most part indicated by the red colour of the ground; though there are exposures near Dinbren-uchaf and along the base of Craig-yr-ogof. When the Rev. James Yates examined the country, in 1825, the latter section was probably more fully exposed; for the débris from the limestone quarries at a higher level is now gradually covering it up, and it is the only exposure worthy of notice. The strata consist of dark red sandstone with some brecciated conglomerate interstratified with it, and the included fragments seem to have been derived from the Silurian rocks. With the exception of some annelid tracks, no trace of any organism has been detected. The fragments of red sandstone and sand of the same colour which occur along the outcrop indicate the probable thickness to be about fifty feet, though the downward extension of the beds is evident over the surface of the adjoining fields. The juncture of the strata with the overlying Carboniferous Limestone is not exposed; but it is certain that the Old Red Sandstone rests unconformably on the Wenlock Shale. According to the sections of the Geological Survey, the thickness of the formation approaches 500 feet; but it is impossible to estimate it with any degree of accuracy.

The Old Red Sandstone is more fully exposed in several places along the west of the Vale of Clwyd, but

particularly at Berllan-bach, near Denbigh, where it is interstratified with the lowest beds of the Carboniferous Limestone; and in Anglesea, where it is more fully developed than anywhere else in North Wales.

CARBONIFEROUS LIMESTONE.

LOWER BROWN LIMESTONE.

This is the lowest subdivision of the Carboniferous Limestone, and it rests conformably on the Upper Old Red Sandstone. Though much obscured by the talus along the base of the Eglwyseg ridge, it is quarried in several places. It is well exposed on both sides of the Ty-nant ravine, at Tan-y-Castell, and in some old excavations on the road below the Trevor quarries. The lithological character of the Lower Brown Limestone is very similar along the whole of its outcrop, and consists of thin bedded dark brown limestone interstratified with partings of shale of the same colour. The limestone strata are usually 9 to 15 inches thick, though sometimes the beds are much thicker, especially towards the upper portion of the subdivision along the western escarpment of the Eglwyseg ridge. At the Trevor quarries the line of separation is very distinct; but in Bron-heulog quarry the juncture is not exposed. The thickness of the Lower Brown Limestone is 480 feet at the Ty-nant ravine, 360 feet at Tan-y-Castell ravine, and probably not above 100 feet at the Trevor quarries, where it has been worked at a lower level. It is not much exposed about Bron-heulog quarry, and has probably almost thinned out there; for at Fron, on the other side of the vale of Llangollen, the Upper Grey Limestone rests on the Wenlock Shale, the underlying limestone not having been formed, in consequence of the rapid *rise of the* sea bottom in which the Carboniferous

Limestone was deposited. This attenuation of the limestone towards the south-east diminishes the importance of the fault described by Prof. Ramsay, in "The Geology of North Wales" (*Mem. Geol. Survey*, vol. iii, p. 226), and which is the only fault shown on the Map of the Survey. The 12-feet bed at the base of the Lower White Limestone is the lowest that can be seen at the bottom of Bron-heulog quarry. The 20-feet bed of shale represents the top of the Lower Brown Limestone, and it is faulted against the *thick-bed* of the Lower White Limestone. It is well exposed close to the tramway—which crosses it—at the south-east end of the quarry. The same bed of shale is again seen in a similar position above Plas-Ifan, where it is entirely composed of small rounded fragments of slaty rock, evidently derived from the Silurian rocks in the vicinity, proving the deposit to have been formed along the old coast-line. At Bron-heulog quarry a bed of limestone, of which about six feet can be seen, underlies the shale; but there is no other indication of the Lower Brown Limestone cropping out there. The boundary fault runs along in front of the quarry; but the ground is so deeply covered with débris that its exact position cannot be determined. Some limestone is reported to have been obtained below the level of the quarry, and the Silurian rock is known to come in close to where the fault is supposed to be; though it is uncertain as to how far the Lower Brown Limestone has thinned out, because the strata may be thrown down by the fault.

The Lower Brown Limestone was formerly burnt for lime, and also used in glass-making; but it is not in request now for either purpose. The strata occur in a very inaccessible position, away from the canal and any good road, which is probably the cause of the limestone not being worked at the present time.

The shale associated with the limestone contains many minute crustaceans *Leperditia suborbiculata* and obscure impressions of plants. The most characteristic fossil is *Productus comoides*, which is very abundant in both limestone and shale. The following species are also common:—*Nautilus globatus*; *Euomphalus Dionysii*; *Murchisoniæ Verneuliana*; *Spirifera lineata*; *Productus cora*; *P. punctata*; *Alveolites septosa*; and *Syringopora geniculata*.

LOWER WHITE LIMESTONE.

The next subdivision in ascending order is composed of three thick and some inferior thin beds of white limestone, interstratified with several beds of reddish shale of a concretionary character, all of which are exposed in the Trevor quarries. The following is a section of the strata of the Lower White Limestone and some of the upper beds of the Lower Brown Limestone beneath, as they occur in those quarries:—

		FEET.	IN.	
Lower beds of Upper White Limestone.	Limestone			
	Concretionary Shale	7	0	
	Shale	3	0	
		10	0	

		FEET.	IN.	
Lower White Limestone.	Limestone	24	0	
	Shale	2	0	
	Limestone *thick-bed*	46	0	
	Shale	1	6	These beds vary considerably.
	Limestone	5	0	
	Shale	1	6	
	Limestone	6	0	
	Shale	11	0	
	Limestone	20	0	Basement-bed.
		117	0	

		FEET.	IN.	
Upper beds of the Lower Brown Limestone.	Rubbly Limestone.	6	0	These beds vary considerably.
	Limestone	6	0	
	Rubbly Limestone.	6	0	
	Shale	3	0	
	Limestone	12	0	
		33	0	

The Lower White Limestone is exhibited in the following woodcut of the farthest Trevor quarry, opposite Castell Dinas Bran, at a right angle to the tramway (under the letter *a*) with the fault, No. 2 plate 4, to which frequent reference is made:—

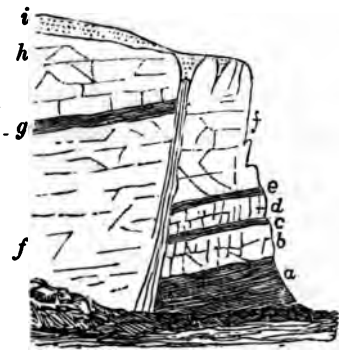


FIG. 1. FAULT NO. 2 IN THE TREVOR QUARRIES.

i. Drift—2 ft.
h. White Limestone—24 ft.
g. Shale—2 ft.
f. *Thick bed*—46 ft.
e. Shale—1 ft. 6 in.
d. Limestone—5 ft.
c. Shale—1 ft. 6 in.
b. Limestone—6 ft.
a. Shale—11 ft.

The *Basement-bed* is below the Shale, *a*.

The *thick-bed* of limestone forms the precipitous scar along the front of the Eglwyseg ridge, to which frequent attention has been directed. It is this bed and the one over it that are principally worked; but the lower beds of interstratified limestone and shale with the *basement-bed* are exposed along the tramway and floors of the

quarries. The continuous and rapid changes in the character of the shales are very remarkable. A few yards often produces a difference in the section, and there is usually a complete alteration in a hundred yards. The thicker overlying beds, however, preserve their uniform appearance, with the shale parting between them over a considerable area.

At Bron-heulog quarry farther to the south-east the Lower White Limestone is again exposed at a much lower level and the *thick-bed* is near the bottom, with three compact beds of limestone below it; but with much less shale associated with them than in the corresponding section at the Trevor quarries. The following is a section of the whole of the strata from the top of Pen-y-gloppa, the scar of Upper Grey Limestone, down to the lowest beds exposed in the quarry, including those of all the four subdivisions into which the limestone is divided.

		FEET.	IN.	
Lower beds of the Upper Grey Limestone.	Denuded surface.			
	Limestone, light grey..	12	0	
	,, grey and thin-bedded.....	54	0	
		66	0	
		FEET.	IN.	
Upper White Limestone.	Limestone and Shale..	40	0	Obscured by base of talus.
	Limestone	7	0	
	Shale	4	0	
	Limestone.....	15	0	
	Shale	6	0	
	Limestone.....	12	0	
	Shale	5	0	
	Limestone.....	9	0	
	Shale	1	0	Correlates with the 8-feet of shale above the 24-feet bed at Trevor quarries.
		99	0	

		FEET.	IN.	
Lower White Limestone.	Limestone	30	0	
	Shale	2	8	
	Limestone, *thick-bed*...	45	0	
	Shale	1	8	
	Limestone	5	6	
	Shale	1	0	
	Limestone	5	0	
	Shale	2	0	Correlates with the 11-feet bed of shale at Trevor quarries.
	Limestone	12	0	Basement-bed. Lowest bed in quarry, and correlates with the 20-feet in the Trevor quarries.
		104	0	

		FEET.	IN.	
Upper beds of the Lower Brown Limestone.	Shale with bands of limestone at the top	20	0	Outside the quarry.
	Limestone	6	0	,,
		26	0	
		295	0	Total.

The passage-beds from the Lower Brown into the Lower White Limestone are better seen at the Trevor quarries than anywhere else.

At Tan-y-Castell ravine the Lower White Limestone is too much obscured by the débris on its successive terraces to admit of the measurement of the separate beds; but the thickness of the whole seems to be about 115 feet. At Dinbren-uchaf, about half-a-mile to the north, the strata are of a massive character, with less shale, as the following section shows;—

		FEET.	
Lower White Limestone.	Limestone	25	
	Shale	5	
	Limestone, *thick-bed*	45	
	Shale	1	
	Limestone	10	
	Limestone with shale partings	10	
	Limestone	25	Basement-bed.
		121	

The following is a section of the Lower White Limestone as presented in the Ty-nant ravine; but they cannot be so accurately measured as in a quarry, and the terraces at the base of the *thick-bed* and other strata are so obscured by débris that the thickness of the beds of shale is doubtful:—

		FEET.	
Lower White Limestone.	Limestone	25	
	Shale	5	
	Limestone, *thick-bed*	45	
	Shale	1	
	Limestone—three beds	15	
	Shale	1	
	Limestone	25	Basement-bed.
		117	

These measurements present a near approximation to the actual thickness in each section, and they so closely agree that it is evident that the subdivision has an average thickness of about 120 feet.

Towards the north the beds of interstratified shale become still thinner, so that Craig Arthur presents a very lofty precipice, for the beds both under and over the *thick-bed* are almost united in consequence of the

absence of shale—except thin partings of it. A mile farther on Craig Aderyn and Craig-y-Forwyn present similar rocky escarpments, beyond which the Eglwyseg ridge subsides into a comparatively flat country.

The Lower White Limestone is used for fluxing purposes, and it can be profitably worked on account of its great thickness and elevated position. The *thick-bed* is, however, in request for its excellent quality.

Fossils are not abundant in the Lower White Limestone, or in the shale interstratified with it. Although the large quantity of limestone that is broken up in the quarries affords facilities for collecting, the number of species is small. The following are the most characteristic, that is, the species which are usually to be found :—*Euomphalus tabulatus; Myacites sulcata; Spirifera bisulcata; Productus cora; P. semireticulatus; Alveolites septosa; Syringopora geniculata; S. ramulosa; Cyathophyllum Stutchburyi;* and *Clisiophyllum turbinatum.*

UPPER WHITE LIMESTONE.

This subdivision consists of a series of beds of light coloured limestone, inclining from grey to buff, divided, at intervals, by shale of a concretionary character, which often graduates into limestone. The beds of shale are less able to resist the influence of the atmosphere than the solid limestone, which has a very compact structure, with very few fossils. The section of Upper White Limestone, at Bron-heulog quarry, (page 180) exhibits the general arrangement of the beds of limestone and interstratified thick shales at irregular intervals; but only 59 feet are actually exposed, and there is no other quarry where the strata have been worked. In the natural sections at the Ty-nant ravine and along the

Eglwyseg ridge, it is evident that the same alternation of the strata prevails, though it is impracticable to draw a correct section, as the beds of shale are nearly always hidden by débris, or the subsidence of the overlying limestone.

The Upper White Limestone, in some of the beds, especially at the Ty-nant ravine, is as compact as lithographic marble; though it varies, and even the same beds are liable to changes. It breaks up along the line of outcrop into large tabular masses very different to the beds of any other subdivision. It never forms a talus of small stones; but breaks off in pieces of a flat tabular form, many being four or six feet across, and where there are smaller fragments they are usually thinnest along the line of stratification. This peculiar arrangement of the broken outcrop of the strata, is caused by the frequent occurrence of beds of shale, which gradually yield to the pressure of the overlying limestone as it breaks off along the outcrop. The flat masses of limestone are very remarkable on the ground. and distinctly indicate the space on every hill-side where the Upper White Limestone crops out. On the Frontispiece, Plate 2, this is remarkably distinct, and the strata may be traced along the successive outcrops in five or six lines of stratification. Lower down in front of the ravine the confused heap of ruinous masses of rock presents a scene of fallen grandeur seldom to be surpassed. Although the Upper White Limestone is more broken down in the Ty-nant ravine in consequence of its steepness, the same rugged outcrop is common to the strata all along the Eglwyseg ridge; though less conspicuous about the Trevor rocks, on account of the subdivision being thinner and somewhat obscured by the fault that runs through the quarries. In Bron-heulog

quarry the same tendency of the Upper White Limestone to break down in tabular masses is again remarkable, and there is an enormous heap of fallen rock in the middle, which has much increased since the year 1873 when the photograph was taken.

The thickness of the Upper White Limestone is 300 feet at the Ty-nant ravine; 250 feet at Tan-y-Castell; 140 feet at Trevor rocks, and 99 feet at Bron-heulog quarry. It has been used for fluxing purposes, but it is not worked at present.

There are very few fossils in the strata of this subdivision. The compact limestone or marble, seldom contains a trace of any, and in no instance are these beds very fossiliferous. In the coarser limestone, however, a careful search will generally result in the following species being found:—*Spirifera bisulcata; Productus giganteus; P. cora; Syringopora geniculata.*

UPPER GREY LIMESTONE.

This is the highest subdivision of the Carboniferous Limestone, and it is well developed along the top of the Eglwyseg ridge, where some of the middle beds form the prominent scar which is so conspicuous, above all the others, with a deep talus fringing its base as shown in Plate 1. The limestone is usually of a dark grey, or slaty colour; but there are some beds of a light grey. The quarry-men call the dark limestone blue, and the lighter strata white, to distinguish the one from the other. The dark grey limestone is usually thin bedded and interstratified with partings of black shale; but the light grey beds are more massive and are principally in the middle of the series, where they are liable to changes in colour within short distances.

It is with great pleasure that I take this opportunity of acknowledging, that I am much indebted to Mr. Isaac Williams of Bron-heulog, for the uniform kindness with which he has assisted me during the survey of the district. He has taken great interest in the subject, and has always been ready to aid me; and I entertain a very high opinion of his practical knowledge, guided as it is by long and shrewd observation in connection with his occupation.

The following is a section of the strata composing the Upper Grey Limestone as measured by Mr. Williams, in the vicinity of the Trevor quarries:—

		FEET.
	Sandy flagstones.	
Upper Grey Limestone.	Light Grey Limestone with quartz pebbles at the top	5
	Dark Grey thin-bedded Limestone	13
	Light ,, Limestone	6
	Dark ,, thin-bedded Limestone	45
	Light and Dark Grey thin-bedded Limestone	33
	Light Grey Limestone	19
	Dark ,, thin-bedded Limestone	24
	Black Shale	2
	Light and Dark Grey thin-bedded Limestone	9
	Light Grey Limestone	12
	Dark Grey thin-bedded Limestone	54
		222
	Upper White Limestones.	

Mr. Williams measured the beds in succession, but considering the difficulty of doing so accurately, I have adopted my own calculated result, which gives a thickness of 250 feet for the whole of the subdivision.

Although these divisional bands of strata are not of any general importance on account of their limited range, they can be identified in the scars and quarries where they occur, and afford the means of ascertaining the amount of denudation when the upper beds of the subdivision have been denuded. The limestone that is worked at the top of the Trevor rocks and in several quarries to the south-east of Bron-heulog, belongs to the 19-feet and 24-feet bands in the section, and in these there are some thinner beds of black shale above the 2-feet bed, in addition to the partings between the beds of limestone. The 12-feet bed of light grey limestone near the bottom of the section forms the scar along the top of the Eglwyseg ridge and that of Pen-y-gloppa above Bron-heulog quarry, as shown in Plates 1 and 3. The thin beds of black shale in the Upper Grey Limestone, present a great contrast to the much thicker beds of the same strata which occur in the subdivision at Minera, Chirk and other places both to the north and south of Llangollen.

The thickness of the strata belonging to the Upper Grey Limestone is 300 feet at the Ty-nant ravine; 300 feet at the Tan-y-Castell ravine; and 250 feet at the Trevor rocks; but further south-east the upper beds are either denuded or thrown down by the fault No. 2, Plate 4, so that only about 66 feet are visible, as at Pen-y-gloppa. The limestone is extensively burnt for lime, but it is only the lower portion that is worked.

Fossils occur in all the strata of the Upper Grey Limestone, though the highest beds are the most fossiliferous, and are well exposed in several small quarries at the top of the Tan-y-Castell ravine, where the upper 24-feet in the section crop out from under the Sandy Limestone. The same strata are also represented by a long narrow heap of loose stones, which

marks the outcrop to the east of the Ty-nant ravine. In the Frontispiece, Plate 2, this fossiliferous zone can be seen extending in the form of a grey line in front of the distant high ground, and it extends along the top of the Eglwyseg ridge for several miles. The strata comprising the 19-feet and 24-feet in the section, however, yield many species, and as most of the quarries are worked in this part of the subdivision, many of the fossils in the list are from those beds. The most abundant species are :—*Bellerophon cornu-arietes; Euomphalus Dionysii; Natica sp.; Spirifera bisulcata; S. crassa; Productus giganteus,* and the young *latissimus; P. punctatus; Cyathophyllum regium; Clisiophyllum turbinatum; Lithostrotion Portlocki; L. junceum,* and *L. irregalare;* and *Lonsdaleia rugosa.*

In these lists the most common fossils have been selected, rather than what seem to be peculiar species, which are usually of rare occurrence. In the list of fossils at the end of the Paper, the horizon of species which have only been found in particular strata is given.

The thickness of the subdivisions and of the whole of the Carboniferous Limestone, at the four localities to which frequent reference has been made, is shown in the following Table; and the thickness at Fron on the south side of the River Dee, a locality to be described hereafter, is appended :—

	Ty-nant.	Tan-y-Castell.	Trevor rocks.	Bron-heulog.	Fron.
Upper Grey Limestone...	300	300	250	66*	80*
,, White ,, ...	300	250	140	99	27†
Lower ,, ,, ...	120	115	117	104	—
,, Brown ,, ...	480	360	100‡	26‡	—
	1200	1025	607	295	107

* Upper portion has been denuded.

† Reposes on the Wenlock Shale.

‡ Lowest beds cannot be ascertained with certainty.

At the Trevor quarries and Bron-heulog the lowest beds of the Lower Brown Limestone cannot be seen, being probably thrown down by the boundary fault, so that the absolute thickness cannot be ascertained. However, at the Fron quarries the upper beds of the Upper White Limestone repose on the Wenlock Shale—the Carboniferous Limestone having thinned out about 900 feet in the four miles south-east between the Ty-nant ravine and Fron. At Tan-y-Castell the attenuation is about 200 feet, so that there are strong reasons for supposing the diminution in thickness to continue gradually with the rise of the Wenlock Shale on which the limestone unconformably rests.

According to the two Horizontal Sections of the Geological Survey the thickness of the Carboniferous Limestone at Dinbren-uchaf a little north-west of the Tan-y-Castell ravine is 1,300 feet, and at the Trevor rocks 1,200 feet. If, however, the thickness is corrected, according to the subdivisions here adopted, it is considerably reduced. The contour of the Eglwyseg ridge allows of this test being accurately applied, and it shows that I have not over-estimated the thickness. In the Survey Sections the base of the Carboniferous Limestone is higher than on the map, and also higher than the one I have assumed in the measurements that have been given, There is an uncertainty about the base line, and if it should occur higher than I have supposed, the thickness of the Lower Brown Limestone would be diminished and the difference added to that of the Upper Old Red Sandstone. Another important difference arises from the Sandy Limestone and part of the Lower Sandstone and Conglomerate to the extent of 200 feet in the Dinbren-uchaf section (No. 39), and 400 feet in the Trevor section (No. 44), being included in the Carboni-

ferous Limestone. Taking all these corrections and differences of the Survey Sections into consideration, the result is 1,100 feet for the thickness at Dinbren-uchaf—half way between the Ty-nant and the Tan-y-Castell ravines—a result remarkably near that I have arrived at; and 1,000 feet about Tan-y-Castell and the Trevor rocks, which is more than I have concluded the thickness to be.

CEFN-Y-FEDW SANDSTONE.

SANDY LIMESTONE.

This forms the lowest subdivision of the Cefn-y-Fedw Sandstone. It is well exposed in a roadside quarry at the turn of the road above Pen-y-gloppa, and in the cliff which runs from it in a north-westerly direction. It is a limestone containing a large proportion of sand, or a sandstone with carbonate of lime as a cementing medium; but it is a very variable bed, some portions being a limestone and others a regular sandstone. The quarry-men call the rock the "flaggy sandstone," and were surprised to hear that it contained lime. The quarry and cliff just referred to are distinctly traceable at the top of the hill on the left-hand of Plate 3. The Sandy Limestone can be traced along the top of the Eglwyseg ridge; but it is generally covered with a peaty soil and consequently cannot be seen except where a few narrow roads have worn down the surface. About the Ty-nant ravine it occupies a considerable area of boggy land, and the strata beneath it can only be seen in a few holes, where water has opened a passage and exposed narrow fissures

in the rock, which seems to be an alternation of sandstone and limestone. Two miles further to the north the Sandy Limestone is a soft sandstone where crossed by a narrow road half a mile north-east of Craig-y-Forwyn. East of the Ty-nant ravine the Sandy Limestone is included in the Carboniferous Limestone on the Geological Survey Map, but in other places it is doubtful on account of the small scale of the 1-inch sheet; on the Survey Sections it is certainly so included. Associated with the Sandy Limestone, east of the latter ravine, there is a bed of dark grey limestone, 11 feet thick, which is evidently near the upper part of the subdivision. It contains numerous Encrinite stems with *Productus giganteus; P. semireticulatus;* and *P. cora,* and is succeeded by yellow flaggy sandstone containing annelid tracks. The limestone can only be traced for about 100 yards along the strike, and does not seem to occur elsewhere on the Eglwyseg ridge. The thickness of the subdivision is about 75 feet, as shown in the Tabular View of the Cefn-y-Fedw Sandstone, Plate 5.

The Sandy Limestone contains fossils, even where the beds are of sandstone, and there is a small opening between Trevor Hall and Trevor-uchaf, where *Modiola sp.; Productus semireticulatus,* and corals too obscure for indentification occur.

LOWER SANDSTONE AND CONGLOMERATE.

This subdivision is directly above the Sandy Limestone, and it always presents an abrupt ascent of the ground, for it is a very hard rock and its base has little or no carbonate of lime in its composition. It invariably forms the highest part of Cefn-y-Fedw and sometimes

crops out through the peaty soil, though more generally the line of strike is indicated by thousands of stones projecting from the surface. The sandstone is very hard and white, and most of the beds, especially near the base, are conglomeratic from the number of white quartz pebbles, less than an inch in diameter, which occur in bands, without any actual separation of the massive sandstone. The rock itself is not much exposed, though it is evidently of a very solid thick-bedded character, and the lower portion of the subdivision forms a rounded eminence, with a semicircular outline, which extends for about seven miles along the highest part of the Eglwyseg ridge, from Garreg Pengruch* to Minera. In Plates 1 and 2 the Lower Sandstone and Conglomerate is the highest visible portion of the hill in the background. The hard white conglomeratic beds seem to be succeeded by sandstone strata of a softer character; but there is no good exposure of them nearer than Minera, where they are exposed in a fine cliff section across the strike of the stratification and are mostly impure limestones; which are coloured Carboniferous Limestone on the Geol. Sur. Map. In that locality the limestone contains numerous fossils; but the conglomerate is very similar to that described. I have not found any fossils in the Lower Sandstone and Conglomerate at the Eglwyseg ridge. Reference has already been made to the contrast between the surface over the Carboniferous Limestone on the one hand, and that of the Cefn-y-Fedw Sandstone on the other; and where the country has not been reclaimed, the geological boundary between the two formations

* Garreg Pengruch is the precipitous hill between Pen-y-gaer and the Monumental Tower, "356" on the 25-in. Ordnance Map; but the name is not inserted.

might be safely drawn, by observing the dry and bright green aspect of the former, and the brown and dreary appearance of the latter.

CHERTY SHALE.

Immediately over the Lower Sandstone and Conglomerate some beds of hard cherty shale crop out, with a general strike from north to south along the middle of Cefn-y-Fedw. This shale occurs in the course of a brook about half-way between the top of the Ty-nant ravine and Tyfyn-uchaf, in a very inaccessible place. About 50 feet of the shale are actually exposed; but it may be double that thickness. It crops out in thin beds of a whitish colour, though somewhat stained to yellow where weathered. It is very hard, and the fine grained varieties closely resemble porcelain; but some of it contains visible grains of crystalline quartz. There is reason to suppose that the cherty shale crops out on the side of Garreg Pengruch, for there is a trail of cherty fragments with fossils on the talus about half-way up. At my suggestion Mr. I. Williams very kindly set a man to try and penetrate to it, but he found the thickness of débris on the hill side so deep that it was dangerous to continue the attempt.

In the Vertical Section, No. 24, of the Geological Survey, which is represented on a reduced scale on Plate 5, a bed of Coal is shown on the horizon of the Cherty Shale, but I have not been able to find any such Coal-seam. Mr. Joseph Davies, of Rhos, informed me that a boring is reported to have been made, about 70 years ago, in the Cherty Shale on Cefn-y-Fedw, and that a bed of coal 3 ft. 6 in. had been discovered, but that he

had not been able to obtain further particulars about it. That the boring may have been made is probable enough, but finding a bed of coal seems very improbable.

The number of fossils in the Cherty Shale is remarkable and includes *Spirifera bisulcata; Rhynchonella pleurodon; Productus semireticulatus; P. punctatus;* and other species too imperfect for determination. *P. semireticulatus* is the most common, and stems of Encrinites are abundant.

MIDDLE SANDSTONE.

This subdivision succeeds the Cherty Shale, and consists for the most part of beds of very hard white sandstone, sometimes like quartzite and often containing scattered quartz pebbles. There are strata of a softer character and yellow in colour associated with the harder beds; though they are not so well exposed and can only be seen on several narrow roads, which cross Cefn-y-Fedw from east to west. The Middle Sandstone crops out at Tyfyn-uchaf and at Garreg Pengruch, at both of which places the hard massive character of the rock is well exposed. That the Cefn-y-Fedw Sandstone is of considerable thickness is proved by its outcrop at Garreg Pengruch, which is the south-east continuation of Cefn-y-Fedw. The hill is 360 feet high, with the base of the Lower Sandstone and Conglomerate on the road below, from which the height was determined, and it is succeeded by the Middle Sandstone with the Cherty Shale between them. The strata dip at an angle of 20°, and as the horizontal distance between the road and the top of the hill is 396 feet, the addition to be made to the height of 360 feet is 136=496 feet. The Middle Sandstone does not, however, terminate at the top of Garreg Pengruch,

for there is a bed of flinty shale, 20 feet thick, followed by about 30 feet of sandstone which are included in the subdivision, giving a total of about 556 feet as the thickness of the Lower and Middle Cefn-y-Fedw Sandstone alone, but in order to guard against an error in the measurement, I have assumed the actual thickness to be 500 feet. The flinty shale is exposed in a field at Pen-y-gaer,* and the overlying sandstone is the bed on which Mr. Whalley's Monumental Tower is built. The following diagram (Fig. 2) exhibits the Cefn-y-Fedw Sandstone at Garreg Pengruch, and the subdivisions into which it is divided :—

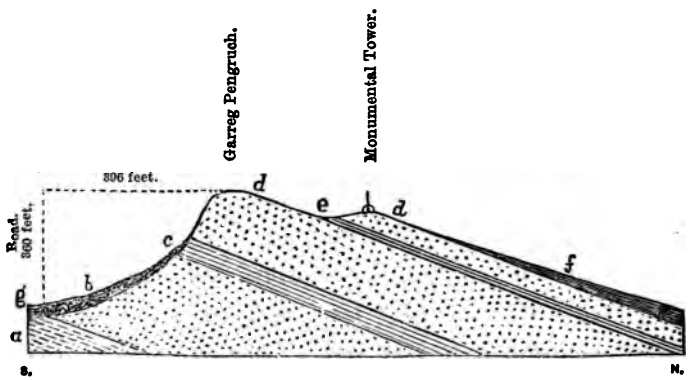


FIG. 2. GARREG PENGRUCH SECTION.

g. Talus on hill side.	*c.* Cherty Shale.
f. Lower Shale and Limestone.	*b.* Lower Sandstone.
e. Flinty Shale.	*a.* Sandy Limestone.
d. Middle Sandstone.	

LOWER SHALE.

This subdivision is fully exposed at Tyfyn-uchaf, where it rests on the Middle Sandstone, and is about

* Ordnance Map 25-in., "1244."

18 feet in thickness. It is chiefly a black shale; but with some bands of impure limestone a few inches thick interstratified with it. The following fossils have been collected:—*Avicula sp.; Posidonomya sp.; Athyris ambigua; Spirifera bisulcata; Streptorhynchus crinistria; Productus semireticulatus; P. longispinus;* and *Chonetes Hardrensis.*

At Garreg Pengruch the Lower Shale reposes on the Middle Sandstone to the east of the Monumental Tower, and the lowest beds can be seen on the hill-side and the road. The higher strata are not exposed, though they probably occur in the fields east of the old limekiln, and seem to have been proved in a trial pit sunk through the overlying Dee Bridge Sandstone on the rising ground near Bryn-Morfydd. The pit was probably sunk in search of fire-clay, when a thin seam of coal, 3½ inches thick, was found. A miner informed me that the same coal-seam had frequently been reached before in the valley, and that it was 10 and 15 inches thick in some old pits that had been sunk. He also stated that it was discovered about 40 years ago in sinking a well. This is the only evidence I have obtained of any seam of coal in the Cefn-y-Fedw Sandstone.

At the Dee Bridge—Pont-y-Cysyllte—near Trevor Station, the Lower Shale is again exposed. It is much thicker than at Tyfyn-uchaf; and probably the same subdivision at Bryn-Morfydd would be found very similar if it were exposed. The strata crop out in the river, and although most of the beds can be examined, it is difficult to measure them exactly, for some are in the water,

and others covered with gravel and stones. However, the following section (Fig. 3) shows the position of the Lower Shale and the succeeding subdivisions.

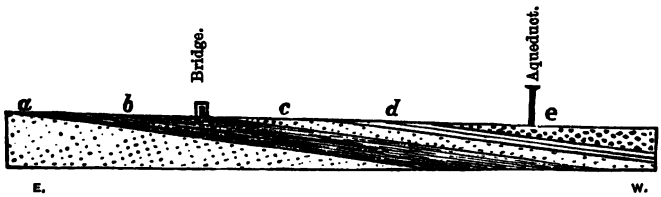


FIG. 3. DEE BRIDGE SECTION.

e. Aqueduct Grit, or Upper Sandstone.
d. Upper Shale. *b.* Lower Shale and Limestone.
c. Dee Bridge Sandstone. *a.* Middle Sandstone.

The Lower Shale at Dee Bridge presents the following beds:—

		FEET.	IN.
Lower Shale and Limestone.	Fire clay	3	3
	Hard brown sandstone	2	0
	Shale, obscured in the water	15	0
	Black shale and limestone	15	0
	Brown sandstone	10	0
	Limestone	1	6
	Shale, said by a miner to contain mussels	4	0
		50	9

DEE BRIDGE SANDSTONE.

This sandstone subdivision succeeds the Lower Shale, and is fully exposed at Tyfyn-uchaf. It is a bedded yellow sandstone, jointed, and very different to any of

the underlying sandstone. It is 30 feet in thickness, and contains plant remains:—*Stigmaria* and *Calamites* associated with several annelid tracks.

At the Dee Bridge section the position of the sandstone is so well seen above the Lower Shale that I have named it from the bridge, the piers of which rest upon its lowest beds. It is about 30 feet thick, and exactly resembles the same subdivision at Tyfyn-uchaf. It also contains impressions of plants: – *Stigmaria* and *Lepidodendron.*

This sandstone in the trial pit at Bryn-Morfydd presents its usual aspect, and contains annelid tracks as at Tyfyn-uchaf, though no remains of plants were observed.

UPPER SHALE.

This band of shale succeeds the Dee Bridge Sandstone. It is not much exposed at Tyfyn-uchaf, but is visible at the east of the Dee Bridge, cropping up at the sides of the river. It is not a subdivision of much importance, except that it extends over a considerable area beneath the following and overlying deposit. A trial pit recently sunk in the Aqueduct Grit quarry at Mount Pleasant, near Bryn-Morfydd, was abandoned after passing through 10 feet of shale which seems to belong to this subdivision.

AQUEDUCT GRIT.

This subdivision is very important for its distinct lithological character, and for the large area over which it presents a uniform thickness. At Tyfyn-uchaf it is exposed in a large quarry, with a bed of shale, 30 feet thick, and the Aqueduct coal resting on it. At the Aqueduct,

east of Dee Bridge, it is also exposed on both sides of the river, with another thick bed of shale, 50 feet thick, above it. At Australia, near Trevor Station, there is a large quarry of the Aqueduct Grit, which is faulted against the thick shale which usually overlies it. This shale is worked as brick-clay at Messrs. Mason and Shelmerdine's brick and tile works, and the following is a section for which I am indebted to them :—

	FEET.	
Coal.....	2	Aqueduct Coal.
Sandstone	6	
Shale.....	48	
,, ...	5	
Coal, 1 ft. 6 in. to	2	Chwarele Coal.
	63	
Aqueduct Grit	70	(75 feet in bore hole on account of the dip.)

The Aqueduct Grit closely resembles typical Millstone Grit, and it is the same rock as the Garth Stone, a well-known building material which has been used in the neighbourhood of Llangollen for more than 500 years. Valle Crusis Abbey, Llangollen Bridge, Carnarvon Castle, and docks at Bristol are built with it. The Aqueduct Grit is supposed to extend over an area of ten miles, and it can usually be recognised in a hand specimen. This grit is the uppermost subdivision of the Cefn-y-Fedw Sandstone.

The following (Fig. 4) is a section from the bottom of the Tynant ravine across Cefn-y-Fedw in an easterly direction to Tyfyn-uchaf, near Trefechan, a distance of three miles. It is the typical section of the Lower Carboniferous Series, and the lower strata are the same as those shown in the Frontispiece, Plate 2. Each

subdivision of the Carboniferous Limestone and Cefn-y-Fedw Sandstone is presented in regular succession, and the thickness of the whole is about 1923 feet.

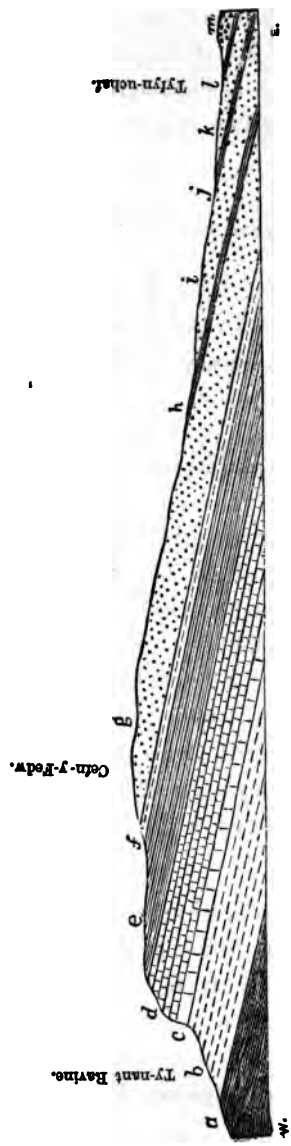


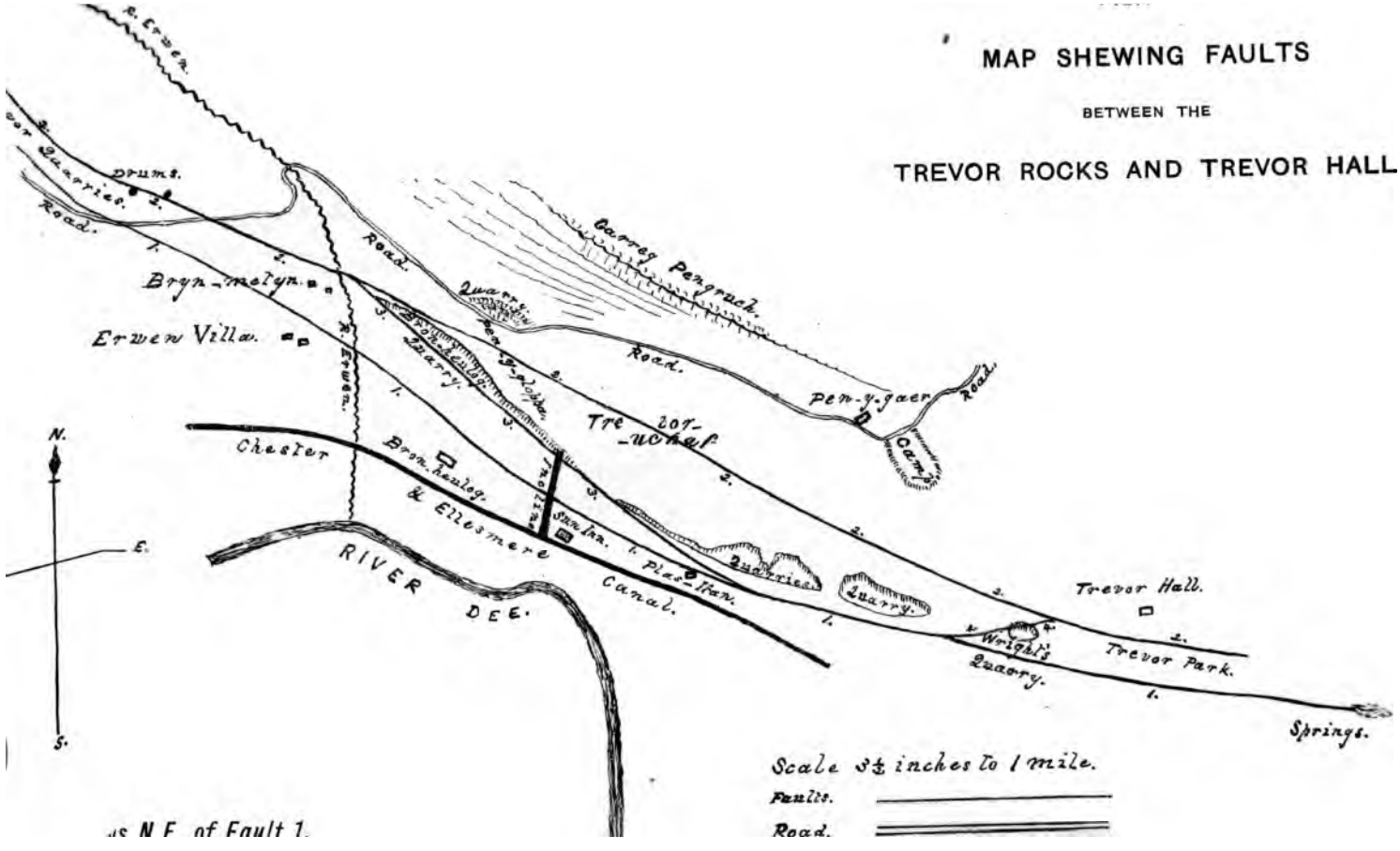
FIG. 4. CEFN-Y-FEDW SECTION.

m. Aqueduct Grit, or Upper Sandstone.
l. Upper Shale.
k. Dee Bridge Sandstone.
j. Lower Shale and Limestone.
i. Middle Sandstone.
h. Cherty Shale.
g. Lower Sandstone.
f. Sandy Limestone.
e. Upper Grey Limestone.
d. Upper White Limestone.
c. Lower White Limestone.
b. Lower Brown Limestone.
a. Old Red Sandstone.

MAP SHEWING FAULTS

BETWEEN THE

TREVOR ROCKS AND TREVOR HALL





The subdivisions of the Cefn-y-Fedw Sandstone seem to be of more uniform thickness than the underlying Carboniferous Limestone; but there are not the same facilities for measuring them. The only section where the Cefn-y-Fedw Sandstone presents a steep escarpment is at Garreg Pengruch, above Pen-y-gaer, where it has already been shown to be 500 feet thick; but the deep talus which covers its steep slope prevents the thickness of the lower strata being so accurately measured as in the underlying limestone. The lithological character of each subdivision presents remarkable uniformity; but beyond the prescribed limits, both to the north and south, differences begin to appear, and great changes are presented as the distance from the typical district increases. The correlation of the subdivisions is shown on four vertical sections on Plate 5, viz.:—Tyfyn-uchaf, Garreg Pengruch, Dee Bridge, and at Newbridge and Acrefair—the latter being a reduced copy of the Vertical Section (No. 24) of the Geological Survey. The general resemblance of these sections to each other is remarkable, and as the strata in the three first named localities are well exposed, especially the Upper Sandstones and Shales, it is evident that the succession has been made out with accuracy. I have not been able to discover the source of the Survey section, but conclude that it was either from borings in search of coal, or an epitome of general observations over Cefn-y-Fedw and in the Dee Bridge section, though Newbridge and Acrefair are the localities given.

FAULTS.

The faults that have broken up the Carboniferous Limestone in the Eglwyseg ridge are of considerable interest and importance. They were probably all pro-

duced at the same time, when the strata were thrown up to the south-west-south during the Permian period. Although there are four faults, they may be collectively considered to be a compound fracture, for they are intimately connected with each other. Plate 4, is a ground plan of these faults, and although it may not be correct in all its details, it is the result of careful observation over a lengthened period.

Fault No. 1, Plate 4, is the boundary fault by which the Wenlock Shale is thrown up, and the Carboniferous Limestone let down; but to what extent it is impossible to ascertain. It is laid down on the Map of the Geological Survey, and appears to throw down the Old Red Sandstone, Carboniferous Limestone, and, finally, the Cefn-y-Fedw Sandstone against the Wenlock Shale; and had I not discovered the attenuation of the limestone in a south-easterly direction, it must have been described as a more considerable fault than it really is. It seems to be an important fault at the east-south-east end, where it brings the Cefn-y-Fedw Sandstone into contact with the Wenlock Shale; but not of much importance between Castell Dinas Bran and the Eglwyseg ridge. This fault is not exposed anywhere about the base of the limestone talus, though its position has been closely determined; for below the Trevor quarries the Wenlock Shale is seen on the road near the spot where the cross-road branches off towards Llangollen; and a little to the south-east along the same road the limestone strata are turned up —30°—probably in consequence of the downthrow on that side of the fault. Although little is actually known of this fault, its course has been traced with tolerable certainty from near Tan-y-Castell, in a curved line to the Park in front of Trevor Hall, and it may have some connection with the springs just beyond that place.

Fault, No. 2, may be a bifurcation of the boundary fault, No. 1, and branch off from it to the east of Trevor Hall. From there it runs west-north-west up a valley, with the Sandy Limestone on one side, and first the Upper White Limestone and then the Upper Grey Limestone on the other—the highest beds of the subdivisions having been denuded. The course of the fault is then across the scar above Bron-heulog quarry, at the north-west end of which, by the Erwen, it unites with fault, No. 3, when the two form a single dislocation, continuing parallel with the incline and through the Trevor quarries, where it can be seen in several places. It runs along the strike of the Lower White Limestone, and throws the beds down to the north-east-north about 20 feet, so that on crossing the fault the *thick-bed* is that much lower than where worked at the outcrop along the Trevor rocks. The dislocation, however, caused by the fault seems to increase in amount as it runs east-south-east, and it causes the massive beds of the Lower White Limestone to present an imposing scar; though the grand precipitous wall of limestone has been almost destroyed by the quarrying operations. Towards Trevor Hall where the Lower White Limestone is brought up against the Sandy Limestone the dislocation is still further increased.

Fault, No. 3, strikes north-west from near Plas-Ifan, at a slight angle to the boundary fault, No. 1, through some old excavations and Bron-heulog quarry, at the north-west end of which it runs into No. 2, near where the tramway crosses the brook. It can be seen exposed in sections at several places along its course, throwing up the thick shale-bed belonging to the top of the Lower Brown Limestone about 50 feet, against the *thick-bed* of the Lower White Limestone, particularly at the south-east

end of Bron-heulog quarry, close to the tramway, where it can be seen on Plate 3. The juncture of this fault with No. 2 cannot be seen for it is beneath the tramway; but the disturbed condition of the strata close to it can be observed in the quarry, about the place where it has encroached on the footpath which winds up the side of it.

Fault, No. 4, is a cross fault from No. 1 to No. 2, and it runs through Wright's most eastern quarry. It is of less importance than the other faults, though the dislocation caused by it is remarkable—175 feet—bringing up the Lower White Limestone on the south-east-south side against the lower beds of the Upper Grey Limestone on the other.

To ensure accuracy, these faults were drawn on the 25-inch Ordnance Maps, and the ground plan, Plate 4, is reduced to the scale of three and a half inches to the mile. That the faults are intimately related to each other is evident from their being downthrows to the north-east-north; and it seems that when the strata were thrown up in the opposite direction, they broke off, and formed a series of fractures, all having a downward tendency in opposition to the upheaving influence of the boundary fault.

MINERAL VEINS.

It is remarkable that no mineral veins of any importance occur in the Eglwyseg ridge; while only five or six miles to the northward there is the rich mining ground of Minera. Reference has been made to the diminution in the thickness of the beds of shale, interstratified with the limestone as they continue northwards. At Minera the Upper and Lower White Limestones form one series of strata, in consequence of the absence of shale and the solid-bedded character of the rock; and it seems

very probable that the shale associated with the limestone in the neighbourhood of Llangollen, may have found its way into the open faults and fissures and prevented the deposition of metalliferous deposits.

DENUDATION.

The recession of the upper beds of the Carboniferous Limestone and Cefn-y-Fedw Sandstone along the top of the Eglwyseg ridge is a remarkable illustration of subaerial denudation. This receding contour has been determined by several conditions, but principally by the more exposed position of the highest beds to the disintegrating action of frost, which breaks up the sandstone for it yields sooner to its influence than limestone. The Cefn-y-Fedw Sandstone has been denuded from the front of the ridge, and the hard beds of the Upper Grey Limestone present a precipitous scar, which continues unbroken except where the ravines run deeply into the ridge. Lower down the thicker beds of limestone form cliffs, while the thinner limestone and shale disintegrate, and terraces are formed over the massive beds; in this manner the *thick-bed* of limestone presents the most precipitous scar, and it is succeeded by the widest terrace.

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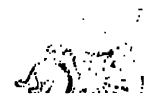
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PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE EIGHTEENTH.

1876-7.

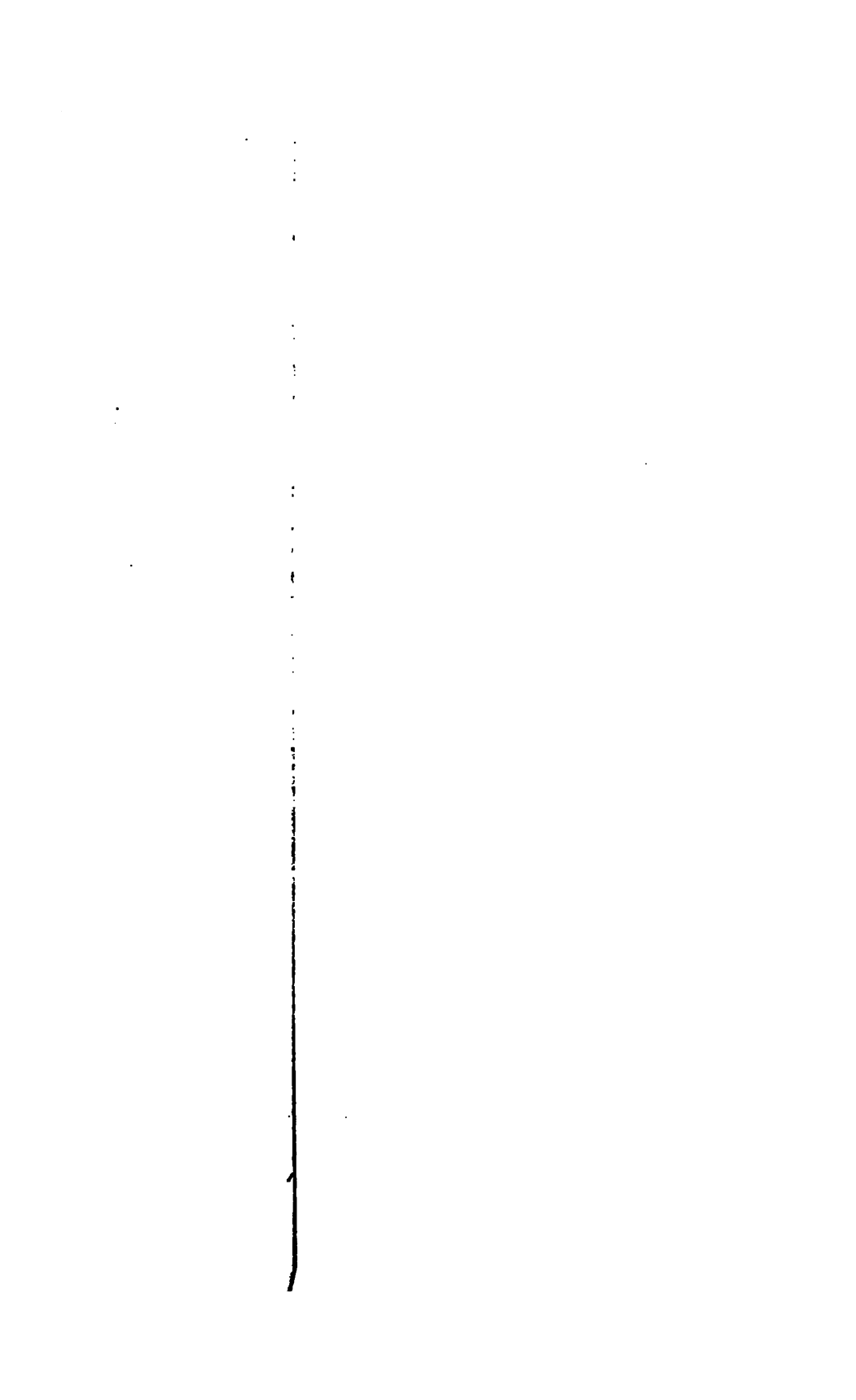
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PART III.—VOL. III.

LIVERPOOL:
C. TINLING & CO., PRINTERS, VICTORIA STREET.

1877.





h Rainfall Area and Group of Strata in England and Wales.

Total Tons of Water per Annum.	Solids in Solution, Parts per 100,000.	Total Solids in Solution, in Tons.	Total Solids in each Rainfall Area, in Tons.
2,957,568,000	4·7	139,000	
			139,000
7,271,968,000	5·0	363,590	
893,692,800	5·5	49,150	
4,129,452,800	12·1	499,660	
			912,400
6,842,480,640	5·6	383,170	
5,722,252,800	5·7	326,160	
5,297,941,760	12·9	683,430	
			1,392,760
2,671,776,000	5·0	133,580	
787,888,000	10·0	78,780	
2,065,040,000	10.8	223,020	
238,318,080	4·7	11,200	
4,035,450,880	26·0	1,049,210	
642,816,000	14·5	93,200	
1,446,336,000	17·7	256,000	
8,251,152,000.	12.0	990,130	
			2,835,120
9,520,748,800	18·4		1,751,810
5,676,054,400	23·6		1,339,540
68,450,936,960			8,370,630

Solids removed in Solution = 143·5 tons per square mile per annum.

et to the Ton, = 125,559,450 feet, or = ·0077 of a foot per century, or *of one foot of matter* soluble in rain water.

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OF THE

Liverpool Geological Society.

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PART III.—VOL. III.

LIVERPOOL

COURIER PRINTING WORKS, VICTORIA STREET.

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1877

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PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION EIGHTEENTH.

OCTOBER 10TH, 1876.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

JOSEPH T. STOWELL was elected an Ordinary Member.

The President read the Annual Address.

PRESIDENT'S ADDRESS.

SINCE the time when Hutton laid the foundation of our present knowledge of Physical Geology, our acquaintance with the structure of the Earth has advanced with rapid strides. The various formations have been reduced to order and sequence through the combined influence of Palæontology and careful Stratigraphical Surveying. But to make Geology essentially a science, the mathematical method must step in to measure, balance, and accurately estimate.

Though fully recognising that there still remain vast and varied unexplored fields for original research, the direction of advancement will be towards reducing those comprehensive generalisations for which we have to thank the old generation of Geologists—now almost passed away—and their rough though wonderful approximations to truth, to careful and accurate measurement.

Instead of giving you, as is usual on these occasions, a *resumé* of geological progress during the year, I purpose devoting the time to what I trust will prove in my case

more valuable, viz., an investigation of the nature and amount of the solvent action of rain-water upon the crust of the earth, and its influence in that direction as an agent of denudation.

There have, as you know, been various estimates made of the amount of mechanical denudation caused by rain, calculated upon the amount of mud held in suspension and carried annually to the ocean by our great rivers; and all of us who prize Lyell's Principles will remember the masterly manner in which he treats the question in the case of the Mississippi and the Ganges, with the Brahmapootra. Other geologists have also calculated from the same data and the area of the river basins, the amount of time it takes to reduce the whole of these river basins one foot in depth; the result being in the case of the Mississippi 6,000 years, and the Ganges 2,300 years.

There have also been estimates of the amount of carbonate of lime carried into the sea annually by the Thames and other rivers draining calcareous districts; but, even if they exist, I am not aware of any attempt having been made to estimate as a whole the soluble constituents removed annually from the varied formations which constitute the crust of the earth. Most of you, no doubt, are aware of the valuable information contained in the Sixth Report of the Rivers Pollution Commission, and the wonderful elaboration and accuracy of all the information relating to the potable waters of Great Britain.

When first I turned over its pages, it at once occurred to me that here is the very thing which a geologist wants for the solution of several interesting problems. I made up my mind that I would use it on the very first opportunity. The present I consider a suitable occasion. In

page 131 of the report is a table of the average composition of unpolluted potable waters, commencing with rain water, but it is chiefly the upland surface waters that I purpose dealing with to-night. In the first column we get the "total solid impurity," which means the total ingredients held in solution, consisting practically of the *soluble inorganic ingredients*, as the proportion of organic constituents is almost invariably very weak. For an explanation of the other columns I quote from a letter Dr. Frankland kindly sent me, and without which I could have made but a limited use of the stores of information collected, through the analyses having been made in a form suited to the immediate object of the Commission. He says:

. . "'*Ammonia*' is generally present in very small quantity, and may be left out of consideration. It is probably always present as Carbonate of Ammonia, and is therefore an *in*organic constituent.

'*Nitrogen*' as nitrates and nitrites means almost invariably nitrogen as nitrates, since the occurrence of nitrites in any but shallow well water is exceedingly rare. If you multiply the numbers in this column by six, you will obtain with close approximation the weight of nitrates in the water.

'*Chlorine*.'—This exists practically as 'chloride of sodium,' and if you multiply the numbers in the chlorine column by 1·65, you will get approximately the proportion of common salt. 'Temporary hardness' means in most cases (except water from Dolomite or Coal-measures, in which there is a good deal of carbonate of magnesia) carbonate of lime, with a little carbonate of magnesia.

'*Permanent hardness*' means, except as aforesaid, hardness produced by sulphate of lime; and if you multiply the numbers in the column by 1·36, you will

get approximately the proportion of *sulphate of lime*, with a little sulphate of magnesia.

Of ingredients of any importance there only remain: Alkaline sulphates—that is, sulphate of soda and sulphate of potash.

Carbonate of Soda.

Silica.

Iron.

Of these, the last two are rarely present in any but very small proportion—about 1 part of silica and 0·1 part of peroxide of iron in 100,000 parts of water."

With this preliminary information I proceed to explain my application of the data for a solution of the problem before us—that is, the estimation of the total solids annually removed by the solvent action of rain from the surface of England and Wales.

To have guaged every river and stream delivering into the sea during a period of say ten years, and to have analysed the water in each case from day to day under the varying circumstances of the dry weather and flood flow, would no doubt have been the most accurate way of determining the question. It is needless to say such a course is fraught with too much labour and expense to be practicable to any individual. There is, however, another method used by engineers, accustomed to design water-works, for estimating, in the absence of gaugings, the flow off the land which gives us what we want with sufficiently close approximation.

By taking the mean rainfall over a given area, and then allowing a certain depth for evaporation and absorption, with judgment, the flow off the land can be arrived at with tolerable accuracy. In the case of several rivers, through elaborate gaugings and observations of the mean *rainfall of* the basin, it is known with certainty what the

proportion is. In the Thames basin, for instance, with a mean rainfall estimated at 27 inches, only 8 inches reaches the sea; whereas in the basin of Loch Katrine, in the area of rainfall exceeding 75 inches of Symons' Hyetographical map, 81·7 inches, according to Bateman, and at Rivington Pike, in the area of between 40 and 50 inches of the same map, according to Stephenson, 39·8 inches runs off the ground. The yield of a gathering-ground is in all cases determined by the total rainfall, the nature of the rocks, and the steepness of the land surface.

In a porous area and small rainfall, like the Thames basin, the maximum of loss takes place, measuring in that case 19 inches per annum; while in the mountainous tracts of siliceous rocks in Wales and Cumberland it is doubtful if more than 10 inches is lost.

My method of procedure thus has been to take out the areas of rainfall from Symons' Hyetographical map attached to the report, to allow to the best of my judgment for evaporation, and then, grouping the formations together in each rainfall area, to estimate the number of tons of water yielded by each gathering-ground annually. Instead of, however, taking out each group exactly as given in Dr. Frankland's table referred to, I have roughly divided them where it could readily be done; and in other cases, judging their relative proportions, I have added up the figures opposite the "Total solids in solution" given for surface water off each formation, and then averaged the results before multiplying the total yield of water by the fraction of 100,000 in that way obtained. I consider that this method is more likely to be near the truth than a more minute analysis. A reference to the table prepared will, however, explain the operation better than any description by me. I have exercised very consider-

able care in the calculations, so I trust they may be relied upon as close approximations.

As there is a certain amount of chloride of sodium in most rain water, due to the spray of the sea being carried inland, I have deducted the average amount from the "Total solid impurity," as not being a product of denudation; but I have not deducted the other solids in solution in the rain, for primarily they must emanate from the land itself. This, however, is but a small fraction of the whole.

Looking at the more remarkable features developed by this analysis, perhaps the one I was least prepared for is the curious way in which the smallest percentages of solids in solution, such as is contained in water from granitic and metamorphic rocks, rise in the aggregate, through the greater rainfall on these formations, to the total solids in solution from such specially soluble rocks as constitute the Thames basin.

With few exceptions, in England the greatest rainfall follows the older formations, whether as cause or effect it is difficult to say; but the older formations constituting the higher grounds they collect more rain, while the denudation being so much greater has no doubt had a tendency to cut down the rocks formerly overlying them so as to expose the old rocks forming the core beneath. Will not this help us to understand those grand examples of denudation in Wales so forcibly shown by Ramsay to have taken place, and which I called your attention to in my last address.

Is it not strikingly apparent from this what a leveller the rain is? Certainly it was never brought to my mind so vividly before.

A reference to the Geological and to the Rainfall maps of England, and a comparison of them, shows that the

mountainous districts, generally composed of rocks from the Cambrian to the Carboniferous, being situated on the west coast intercept the greatest rain, which is from the south and north-west, and that here in Devon, Wales, and the Lake district of Cumberland and Westmoreland, the rainfall ranges from 50 to over 75 inches.

The extremes of rainfall in 1874 were at five stations in the Lake district, from 107·53 at Little Langdale to 148·79 at Seathwaite; while in Wales, at three stations, it was from 116·56 to 149·00 inches. The smallest, as might be expected, was on the east coast, ranging from 12·85 at Chatteris, in the Isle of Ely, to 14·97 at Ipswich; and in Wales from 22·33 at Holywell, to 27·96 at St. Asaph.

The rainfall, expressed in inches, if distributed evenly over England and Wales, would have been for 1874, 34·02, or 1·50 below the average from 1860 to 1865, if we take the mean of all the stations. Estimated, however, by areas, as given in Symons' map, the mean rainfall of England and Wales, is 31.988 or say 32 inches.*

Dividing the country in sections, as shown in the table, and estimating each separately, gives a total of 68,450,936,960 tons of water run off the area of England and Wales annually, equal to 18·3 inches in depth, which leaves 13·7 inches for evaporation.† The total solids in

* The difference arises from the fall at some of the mountain stations being much in excess of the average; and the areas of this excessive fall being restricted, the mean of all the principal stations naturally gives the excess we see. Mr. Symons, in a letter to me, says he has never worked out the mean rainfall, but is "under the impression it would come out about 35 inches."

† It must not be lost sight of that it is the *evaporation* only that affects our calculations. Water that *percolates* will find its way eventually into the river system, or directly by springs into the sea itself. This water is, of course, more highly charged with mineral matter than surface water, and may help to balance flood surface water, which often contains less than the mean quantity of soluble mineral matter. On the whole, it will be seen that the figures work out fairly in unison with each other.

solution amount to 8,370,630 tons, or 12·23 parts in every 100,000 of water. This total includes, calculating on the method pointed out by Dr. Frankland, and on the averages of the samples 9·50 parts of the carbonates and the sulphates of lime and magnesia, the sulphates predominating in the averages of the water from all the rocks below the New Red and the carbonates in those above the Permian, reaching its maximum in the cretaceous. The average amount of chloride of sodium, deducting ·36 as that contained in the rain, is 1·66 for the upland waters. The nitrates amount to ·08.*

There is now left ·99 for the alkaline sulphates and carbonates of soda, silica, and peroxide of iron.

I have intentionally taken the upland surface water as a Geological basis to work upon, for in consequence of drainage works, artificial manures, and other disturbing causes incidental to a thickly populated country, the primitive denudation of the world is not accurately represented by the constituents held in solution in most of our river waters far down their course. The chloride of sodium in the Thames water, for instance, as supplied by five different companies, averaged in 1873 3·1 parts in 100,000, and most of this is no doubt of artificial origin. In the Mersey at its junction with the Irwell the chloride of sodium is 4·12, and in the Irwell at its junction with the Mersey it reaches the enormous amount of 21·28 per 100,000.

Again, the drainage and culture of calcareous soils adds considerably to the amount of the carbonates and sulphates of lime held in solution, and these disturbing

* The averages of all the samples of upland water give 12·66 as the total solids in solution, which is a very close approximation to the 12·23 estimated in the totals as before described, and is calculated to verify the accuracy of the method I have adopted.

causes I have endeavoured to eliminate from my calculations.

If we may estimate the various solids held in solution at 15 feet to the ton, the weight of limestone,* the amount of denudation if distributed equally over the area of England and Wales reckoned at 58,300 square miles would be .0077 of a foot per century, that is it would take 12,978 years to reduce it one foot.

It is certainly a rather remarkable coincidence of figures that Professor Prestwich, I find, in his address to the Geological Society of London, 1872, calculates that the Thames removes from the Chalk, Upper Greensand, Oolitic strata and Marlstone, carbonate of lime alone to the extent of 1 foot over its basin in 13,200 years. This he arrives at by referring 10 grains to the gallon on the total discharge at Kingston to these strata, estimated at 2072 square miles. The total denudation due to solids in solution over the whole area is, as will be seen further on, 149 tons per square mile per annum, as against 140 tons of carbonate of lime alone removed from the restricted area calculated by Professor Prestwich.

Taking the carbonates and sulphates of lime and magnesium at 9·5 and 15 feet to the ton, that would represent the removal of those substances in solution at the rate of 1 foot in 16,707 years.

The Chloride of Sodium estimated at 1·66 would represent the removal of 1 foot in thickness (16 feet to the ton) of Rock Salt in 89,640 years.

The remaining portions consisting of Silica, Alkaline Sulphates, Peroxide of Iron, &c., have not been directly determined by analysis, and are therefore only very

* Some very compact limestones only contain 13 feet to the ton.

rough approximations. The analyses of river waters by Bischof* shew these ingredients to be very variable, even in the same river at different times. If we estimate them at 12 feet to the ton, ·99 parts per 100,000, would give 200,405 years to remove 1 foot in thickness.

After very carefully reviewing my data and calculations, I am of opinion that these figures in the main represent very nearly what would be the denudation of England and Wales in their primitive condition, before the hand of man had interfered much with the surface.

If, however, we desire to know what is now being removed, I think we must increase this estimate by one-fifth, as Dr. Frankland's analyses clearly shew that cultivation of the land, and drainage especially in calcareous districts, increases the soluble substances in the water to a very considerable extent.

It would have been impossible to rely upon the data had not a very great number of samples been analysed, taken, be it observed, at all seasons of the year, for we find these averages tend to correct one another, and to give a very close approximation to the aggregate result.

Stated simply, this then, is the result. If we imagine the area of England and Wales, consisting of 58,300 square miles, to form one river basin, the delivery of water by such river would be 68,450,936,960 tons, or 18·3 inches per annum, containing a total of 8,370,630 tons of solids in solution, representing a general lowering of the surface from that cause alone of ·0077 of a foot per century, or one foot in 12,978 years.

Thus far we have got with our geological modulus of time; but before attempting to apply it to the solution of the larger problems of Geology, let us see if we can

* Chemical and Physical Geology, Vol. 1, p. 76.

institute a comparison between England and the other parts of the world best known and Geologically surveyed.

A reference to the Geological Map of the world, constructed by Jules Marcou, shews that in the continent of Europe the principal difference from the Geology of England is the much greater development of what in his classification are Crystalline Rocks, consisting of gneiss, metamorphic rocks, granite, porphyries and trappean rocks, principally situated in Norway and Sweden, and the Tertiaries in mid-Europe, between the Baltic and the Black Seas. Roughly speaking it is easy to see that in England and Wales a line may be drawn, dividing them into two nearly equal halves, on the western side of which are the rocks from the New Red downwards, and on the eastern the rocks from the lias upwards, including the Tertiaries. I have, at considerable trouble, calculated the areas of the several formations of Europe from Jules Marcou's Map.

They are approximately as follows:—

	English Square Miles.
Modern Rocks	468,277.
Tertiary do.	613,043.
Cretaceous Rocks	552,282.
Jurassic do.	246,983.
New Red Sandstone	466,292.
Carboniferous Rocks	181,940.
Paleozoic or Grauwacke	463,661.
Crystalline Rocks	714,960.
Volcanoes and Basalt	13,062.
Total	3,720,500.

It will thus be seen that the formations from the base of the Jurassic up to the Modern Rocks constitute almost exactly half of the continent, and those from the New

Red downwards, inclusive of the Volcanoes and Basalt, the other half; consequently the dividing line is nearly the same in the Continent as in England and Wales. The Geological structure of England is almost an epitome of that of Europe, excepting that in the Continent the Carboniferious rocks are in less force, and the Tertiary and Metamorphic in greater.

The average solubility of the rocks, I suspect, is not very different on the Continent from that of England, but the rainfall is less, averaging, according to Sir John Herschell,* 23 inches for the *non*mountainous districts, and 42 inches for the mountainous ones.

We may, therefore, assume that the total solids in solution removed annually are proportionately not so great as in England, excepting in the Swiss mountains, where, no doubt the denudation is more rapid than in any area in England or Wales.

As bearing upon this comparison, I have collected all the available information I could as to the discharge of several of the principal rivers of Europe; and, though the data is imperfect in many particulars, the facts bear out the views I have just stated.

The Rhine, the Rhone, and the Danube all rise in the Alpine district, and flow to the west, the south, and the east, through formations of which the basin of the Thames and the Severn would form, perhaps, the nearest English equivalents. The basin of the Rhine is rather more than the area of England and Wales; so we may readily institute a comparison between the country drained by the Rhine and England. Above Lauterbourg, its area is 63,000 square miles, and the annual discharge of the river is 34,216,560,000 tons, equal to a depth of 8·53

* Physical Geography, 4th Edition, p. 241.

inches.* The rainfall is from 16·4 inches at Frankfort-on-the-Main to 26·3 at Bonn; but, of course, it is also fed by the Alpine snows through the Lake of Constance. The mean of the analyses of solids in solution, as given by Bischof, is 17·1, say 17 in 100,000, this gives 5,816,805 tons per annum, or 92·3 tons per square mile.

The Rhone at Avignon has an area of 35,745 square miles, and an annual discharge of 53,144,040,600 tons, equal to 22·86 inches in depth. The mean of four analyses given by Bischof is 15·6, which will give 8,290,464 tons of solids removed per annum in solution, or 232 tons per square mile.

The Danube has an area of 310,000 square miles, and the mean discharge into the Black Sea, from ten years' observation is, according to Sir C. A. Hartley, M.I.C.E.,† 207,000 cubic feet per second, equal to 181,332,000,000 tons per annum.

The discharge appears, however, to be very variable, the maximum being 383,000 cubic feet per second in 1871, and the minimum 125,000 cubic feet per second in the years 1863 and 1866.

The rainfall at Sulina also varies from 10·03 inches to 34·28; but whether it is as variable over the whole basin I cannot say.

This discharge equals a depth of 6·8 inches run off the ground, or one-third of the mean rainfall at Sulina. The amount of solids in solution was 12·42 at Vienna. Bischof, however, only gives the one analysis. If this is an average quantity, the total solids in solution would amount to 22,521,434 tons per annum, or 72·7 tons per square mile, or as nearly as possible one-third of the

* Beardmore's "Manual of Hydrology."

† "Minutes of Proceedings of the Institution of Civil Engineers," vol. xxxvi, p. 224.

average amount of matter held in suspension, which is given as 67,760,000 tons, estimated from surface samples.

The total drainage area of these three great rivers is, therefore, 408,745 square English miles, their annual discharge 268,692,600,600 tons, and the total solids in solution 36,628,703 tons.

Comparing this with the calculated denudation of England, it amounts in England to 143·5 tons per square mile and 90 tons per square mile in the three European river basins.

The data for these latter calculations are, indeed, insufficient, more especially as regards the Danube, from the absence of analyses at more points than Vienna. I think it extremely probable that the estimate should be increased, as the direct determination of the solids in solution amounts to 14·14.

The result is, however, in accordance with what we should *a priori* expect; the greater rainfall on the western coast produces its effect upon the land, not only in removing detritus mechanically, but in its solvent action upon the rocks. It works more quickly.

The Garronne removes 142 tons per square mile.

The Seine contains, according to two analyses by Bischof, 21·72 parts per 100,000. The drainage area is at Paris 17,111 square miles, and the discharge equals 6·98 inches per annum; it therefore removes about 97 tons of solids in solution per square mile.

The Thames, estimating the discharge at eight inches per annum and the total solids in solution at 29·26, as given by Prestwich, removes 149 tons per square mile per annum.

It is thus seen that there is much less variation than one would have expected between the soluble constituents

removed by one river and another; for if we compare the maximum of our examples, which is the Rhone at 232 tons per square mile per annum, with the minimum, the Danube at 72·7 tons, we find there is only about the same difference between them as there is between the maximum and minimum annual discharge of water of the Danube itself! If, on the other hand, we compare the quantity of solids in solution removed to the solids in suspension, we find that the former is a much more constant quantity. The detritus carried down to the Black Sea by the Danube was, in 1866, 12,500,000 tons, and in 1871 it rose to 154,000,000.

It is also evident that the character of the solids in solution is determined by the nature of the rocks the water flows over. On the western half of England the sulphates of lime in the upland waters predominate over the carbonates in the proportion of 7·15 to 2·9; while in the Thames area the carbonate of lime is in excess of the sulphate in the proportion of about two to one. It is extremely probable, therefore, that over the whole area of England and Wales the carbonates and sulphates of lime are about equal.

On taking the mean of eighteen analyses of water from European rivers, given by Bischof, I find the carbonates in excess of the sulphates of lime in the proportion of 9·32 to 1·79. Bischof, himself, says, "Among the mineral substances in these rivers, carbonate of lime is always in the largest quantity." The basins of these rivers are, however, composed nearly wholly of the strata above the New Red Sandstone, excepting as regards the Crystalline rocks. The Volga is a river flowing through the New Red; of this water I have no analysis, but, as might be expected, the sulphates of lime predominate over the carbonates in the Caspian

Sea, which receives its waters. The mean of two analyses, one by Göbel, the other by H. Rose, gives 89·6 parts per 100,000 of sulphate of lime to 18·9 of bicarbonate of lime.

It is evident, therefore, that, estimated over the whole Continent of Europe, and taking into consideration the proportions of the various rocks, the carbonates of lime will still be in excess of the sulphates.

The extensive development of Carboniferous strata in England, together with the New Red, to a large extent accounts for this diversity between England and the Continent; but the proportional excess of sulphates of lime in the Thames water over the Continental European river waters may perhaps be partly traced to the more artificial state of the Thames basin. If the information we require is limited with respect to Europe, it is still more restricted in relation to the rest of the world. Of the geology of Asia our knowledge is very partial and very indefinite, as a glance at Jules Marcou's map will show. To calculate the proportion of the various formations would be impossible, with the accuracy required for our purpose. Dr. Frankland has, however, kindly supplied me with several unpublished analyses of water in various parts of the world, and among them is one of Tienshan Lake, in China, in which the total solids in solution are 13·10 per 100,000. Of these 5·31 are due to carbonate of lime and 1·91 to sulphate of lime. The River Wangpoo, above the influence of ordinary tides, has 10·46 per 100,000 of solids in solution, of which 4·14 are carbonates and 1·57 sulphates of lime.

Above the bridge at Wangdoo the water holds 21·54 of solids in solution, of which 9·31 are carbonates and 1·65 sulphates of lime; at Tyking 30·52 of total solids in solution, of which 11·30 are carbonates and 3·88 sul-

phates of lime.* The chloride of sodium in Tienshan Lake amounted to 1·71, and in the Wangpoo to 1·48. The Tisai (Tienshan) Lake, according to another analysis, holds 10·90 solids in solution, of which 5·31 are carbonate and 2·32 sulphate of lime, while the chloride of sodium is 1·73.

There are other analyses by Dr. Frankland, but I cannot make any deductions from them, as the samples were apparently taken within the influence of the tides.

In South America an analysis of the Parana in front of Carabelos gives 10·08 of total solids in solution, of which ·28 was carbonate of lime and 3·03 sulphate, and 2·97 chloride of sodium, the nitrates amounting to ·42.

It is rather a pity this analysis did not determine the separate amount of each constituent, as there is a large balance to be accounted for, viz., 3·38 to be divided between the alkaline sulphates, carbonate of soda, silica, and iron.

I have now pretty nearly exhausted all the information I can bring to bear on what, for brevity, I shall call "*Soluble Denudation.*"

The rainfall is so variable in different parts of the world, that it is difficult to make an estimate of the average "Soluble Denudation" of the globe; but we find that Nature, on the whole, averages the results; and, though there is as much as 300 inches of annual rainfall in some places in the Tropics, and 600 inches, or 50 feet, on the Khāsi Hills at Cherra Poonjee, on the other hand we have great rainless districts in the interior of Africa and Asia. The River Nile, with a basin of 600,000 miles, above Cairo, according to Girard, runs off only 3·78 inches per annum; but this, if the data of my calcula-

* Probably affected by the tide.

tions are reliable, must be in excess of the actual depth.*

The Ganges at Sikreegulee, with a basin of 330,000 English square miles, runs off 20·51 inches per annum; while if we take the Ganges and Brahmapootra together as having a joint basin of 432,000 geographical miles,† equal to 570,240 English square miles, and the joint discharge at 12,736,154,880 cubic feet per annum, according to Lyell's statement, based on Mr. Everest's calculation,‡ the amount run off the ground per annum will be 50·8 inches.

This tremendous depth is due to the rainfall on the Himalayas, and is greater than the Rhone at Geneva, which is 48·20. The Mississippi and Missouri have a basin of 1,300,000 English square miles; and according to Messrs. Humphreys and Abbott, as quoted by Lyell, 132·36 cubic miles of water are discharged annually, equal to 8.19 inches in depth over the whole area.§

Keeping the above facts in view, and seeing how constant a quantity the solids in solution are, for when the rainfall is small the river water as a rule holds a larger proportionate quantity of dissolved matter; and taking into consideration what we know of the geology of the world, I think we have sufficient grounds for a provisional assumption that about 100 tons of rocky matter is dissolved by rain per English square mile per annum.

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* The mean annual delivery of the Nile is calculated by M. Talabot at 101,000 cubic feet per second, and its supposed drainage area, according to Herschell, 520,000 square geographical, or 686,400 statute miles. This would give only 2·01 inches run off the ground. (See Herschell's "Physical Geography," p. 210, 4th Edition.)

† Herschell's "Physical Geography."

‡ "Principles of Geology," 10th Ed., pp. 481–3.

§ This is arrived at by dividing the cubic quantity of sediment by the fraction representing the proportion it bears to the water, that is $\frac{1}{1331}$ Beardmore calculates the depth run off the ground at 8·40 inches.—*"Manual of Hydrology."*

Of this total, if we allot 50 tons to carbonate of lime, 20 tons to sulphate of lime, 7 to silica, 4 to carbonate of magnesia, 4 to sulphate of magnesia, 1 to peroxide of iron, 8 to chloride of sodium, and 6 to the alkaline carbonates and sulphates, we shall probably be as near the truth as present data will allow us to come.

Before leaving the subject, let us now see what light, if any, these figures throw upon geological time.

How can we approach the question? If, as is generally supposed, the sea contains only what is washed into it from the land,* and we can estimate its mineral contents in tons, we at once get a minimum measure of the age of the Earth; whether it will be possible to arrive at a maximum we shall see further on. According to Herschell, the ocean contains 2,494,500 billions of tons of water; and the mean of Dr. Frankland's analyses of sea water gives 48·9 tons of carbonate of lime and magnesia, and 1017 tons of sulphate of lime and magnesia in 100,000 tons. Taking the area of all the land in the world at 51 millions of English square miles, there is in the ocean, in round numbers, 1,222 billions of tons of carbonate of lime and magnesia, or sufficient to cover the whole of it at 15 feet to the ton 12·9 feet thick; and of sulphate of lime and magnesia 25,369 billions of tons, or sufficient to cover it 267·6 feet thick. If, then, we reckon the whole of the sulphates removed from the land at 20 tons per square mile per annum, it would take in round numbers 25

* Herschell says. "Physical Geography," p. 21. As the sea continually receives the drainage of all the land, besides having in the course of countless ages, washed over and over again the disintegrated materials of successive continents, it must of course hold in solution all the saline ingredients capable of being separated and taken up by such lixiviation in cold water; in fact, in greater or less quantity, every soluble substance in nature—such, at least, whose existence in extremely dilute solution are not incompatible.

millions of years to accumulate the quantity of sulphate of lime and magnesia contained in sea water, but only 480,000 years to renew the carbonate of lime and magnesia, at the rate of 50 tons per square mile of land surface per annum. We know, however, that the carbonate of lime is constantly being removed by testaceous animals, corals and foraminifera.

There is also good reason to suppose that the sulphates of lime are also decomposed by decaying organic matter, and we know from numberless analyses that there is always present in sea water a large quantity of free carbonic acid,* which the result of the "Challenger" expedition proves is sufficient to entirely dissolve the calcareous portions of the dead foraminifera before they in sinking reach the bottom of the greater ocean depths.

The quantity of sulphuric acid in sea water also varies considerably. It is probable, also, that marine organisms can in some way directly utilise the sulphate of lime. Bischof shows very beautifully and clearly that the amount of carbonic acid in sea water is subject to very little variation, and that it is present in sufficient quantity to dissolve five times as much of the earthy carbonates as are actually dissolved, and "that the sea water is so far below its point of saturation as regards carbonate of lime, can only depend upon the constant separation of this carbonate by testaceous animals. By this separation, however, the carbonic acid which had dissolved this carbonate always returns again into the sea water. In the sea, therefore, the solution of carbonates and their separation by organic agency go on constantly, no addition of carbonic acid from without being required." He also shows that the carbonic acid which has been

* Bischof, "Chemical Geology," vol. i, p. 103.

removed in the vapour of water returns to the sea by the rivers.

If we turn to the chlorides consisting principally of chloride of sodium, we find the mean of Dr. Frankland's analyses to be 3,259 parts in every 100,000, which gives 81,295 billions of tons; or, at 16 feet to the ton, sufficient to cover the whole of the land 914·9 feet deep! * This is certainly a startling result. Reckoning all the chlorides brought into the sea by the rivers annually at 8 tons to the square mile, it would take, in even numbers, 200 millions of years to renew the chlorides of the sea. I have now, I hope, enabled you to form a quantitative idea of the soluble constituents of the globe, so far as we can measure them in water.

The greater portion of the land of the globe is composed of sedimentary rocks, themselves laid down in the sea, lakes, inland seas, or estuaries.

The constituents of the crust of the earth have been again and again dissolved, carried into the sea, separated therefrom by organisms, or by evaporation from portions that have from time to time been cut off from the general ocean, or in that minute chloride dust Dr. Frankland so beautifully shews is constantly being carried into the air through the spray of every wave. What a lengthened vista does not this disclose?

We cannot see the beginning, all that is plain to us is the sequence, the circulation.

The matter of the world is continually changing place —its solvent is the rain, its carrier the river, its receiver and distributor the ocean. How many times

* As shewing the necessity to the Geologist of a quantatitive knowledge of the constituents of the Earth, even so great a reasoner as Lyell imagines it possible that all the salt in the sea could, during a subsidence of the land, be evaporated in the Runn of Cutch.—See "Principles."

the matter of this solid land on which we stand has been in solution, suspension, or moving to and fro on the shore or the sea bottom, it is impossible to say. In the present state of science it defies calculation to reach a maximum beyond which we can say the age of the earth does not extend, for the calculations based upon the form of the earth and tidal retardation * are fallacious, through leaving out agencies that we know are at work, and which the calculations I have to-night submitted to you bring out in greater force.

I have said nothing as yet of the comparative potency of mechanical erosion as compared with chemical in reducing the crust of the earth. Strictly speaking, one, however, is the complement of the other. The chemical agency decomposes the matrix, and separates the particles, which the mechanical force of the river in flood carries to the sea. The actual degradation of the rocks by mechanical movement of water containing stones, is a very small matter. The effect of tidal action I have before dwelt upon and explained.

The ocean, I consider, acts merely as a mechanical distributer of matter, which has been introduced from the land; and though tidal action has the power in certain cases of excavating very wide, deep, and long gullies in the shallow seas, its effect is limited by the force and direction of the current, so that it cannot work out its hollows beyond a certain depth below the general floor of the sea. The action of subaërial denudation is on the other hand unlimited, except by the sea-level. It can degrade, excavate, and deepen, so long as anything is left above the water.

The amount of matter brought down mechanically into the sea, in the case of the Danube, we see was

* Sir William Thompson.

$\frac{1}{3000}$ of the water, or about three times the calculated solids in solution. The maximum amount being $\frac{1}{465}$, and the minimum $\frac{1}{7300}$. The solids in solution come down constantly; the mud is pushed along in times of flood. According to Messrs. Humphreys and Abbott the solids in suspension in the Mississippi are $\frac{1}{1312}$ of the water. If we were to take the solids removed mechanically and in solution at six times those in solution, which is a very high estimate, we should have over the whole of the globe 600 tons of denuded matter annually per square mile. Taking the sedimentary crust of the earth at ten miles thick throughout—a moderate estimate—and allowing for the denudation of the sea and the amount added to sediments by volcanic ejections, matter equal to one-third that which is denuded from the land, we should have annually removed and deposited matter equal to 800 tons per square mile of land surface, or 40,800 million tons annually. The total surface of the globe is 197 millions of English square miles. A cubic mile of rock at 13½ feet to the ton would weigh 10,903,552,000 tons, so that to cover the whole surface of the globe one mile deep with sediment from the land at the rate of 800 tons per square mile of land surface, would take 52,647,052 years, or 526 million years in round numbers for ten miles deep.*

*It is not necessary for the accuracy of this calculation that the sedimentary crust of the earth should everywhere now measure 10 miles thick, or even that it should average that thickness, indeed if it were so the estimate of time would have to be enormously increased, because the rocks of one formation are largely derived from the sediments of preceding formations, therefore it is probable that the *maximum* thickness of the whole of the sedimentary deposits is a true guage of the average thickness of rock which has been removed by denudation from the entire surface of the globe. The maximum thickness of the whole of the known sedimentary formations is variously estimated at from 14 to 17 miles.

At 13½ feet to the ton, 800 tons per annum would give one foot of denudation of the land each 2,581 years; so it will be seen that the above is a very moderate estimate of the time which has elapsed since the first of the sedimentary rocks, we are acquainted with, were laid down, on the hypothesis that the denuding agencies had the same average potency as now, and that the area of land surface has been constant.

But it will be said—What proof have we that the denuding agencies were not formerly much greater and more active than now? I reply with Lyell: We have no evidence that such was the case.

It is true that, according to fossil evidence in the earlier periods, the earth appeared to be of a more uniform temperature than now.*

This, it seems to me, would act in the contrary direction, and tend to reduce the rainfall, as it is the mixing of air of different temperatures that produces rain. Again, if we assume the land surface to have been proportionately to the sea greater than it is at present, the evaporating surface would have been lessened; in fact, the forces of nature in this, as in other cases, tend to equalise themselves.

In opposition, therefore, to astronomical calculations, I am prepared to maintain the position of Hutton and Lyell. We may speculate on a beginning, but we can find no trace of it by geological methods, for in no respect do these earlier sediments, so far as they have yet been investigated, lead us up to a particular rock from which the first sediments were derived. The beginning may be a logical necessity, and astronomical and mathematical reasoning may eventually throw some

*See Hooker on Carboniferous plants, Memoirs of the Geological Survey, Vol. II. Also papers by Nordenskiöld and Judd in Geological *Magazine* and Dana's Manual of Geology.

light upon it, but before then a multitude of circumstances will have to be considered by the mathematician, which he often ignores, through unfamiliarity with geological reasoning.

The calculations I have had the pleasure of laying before you have been laborious, but they have given proportion and definiteness to my ideas of geological cause and effect, and their relations to time. Probably I have dealt too much in figures to make my address as interesting in its delivery as the subject will be found on closer study. It is so vast and complicated that I cannot hope to have given you more than a faint outline of the whole picture as it presents itself to my mind. The value of figures is best seen by those who work them out; but if I have succeeded in demonstrating that the views of geology taken by our greatest masters come out with greater force and truth, the more they are put to the test of calculation—then I have achieved quite as much as I can expect to do, or could hope that you would patiently listen to.

In resigning the Chair of the Society, I can only express to you the satisfaction it has been to me to meet you all from year to year since I first joined the Society, and during the term of my Presidentship, and to thank you for the uniform consideration and courtesy with which all, I have said, has been treated. In welcoming my successor to the chair, I can only say that we shall all extend to him the same feeling of good fellowship, begotten of kindred pursuits, which will enable him to perform his duties in the satisfactory manner we know he is capable of, and assist him in upholding the dignity of the science we all love.

NOVEMBER 14TH, 1876.

THE PRESIDENT, HUGH F. HALL, F.G.S., in the Chair.

JAMES H. JOHNSON, F.G.S., and WILLIAM H. COOKE were elected Ordinary Members.

The following communications were read:—

SOME NOTES OF THE GEOLOGY OF LONDONDERRY, MADE DURING HOLIDAY RAMBLES IN THAT COUNTY.

BY JAMES L. MCCLAY.

IF, on leaving Derry, you ascend any of the hills which command a view of the valley of the Foyle, you will be much struck with the physical features of the country. You will see that it is all dotted over with hills, many of them of considerable height. For instance, here is Slieve Boe, or the "Hill of the Cow," which is about 1,000 feet high. From the hill between the Foyle and Glendermott on to the Knockanduns, or "Hill Forts," in the parish of Tamlaghtfinlagan, hill after hill meets the view. But there is one thing which can be seen from the valleys of the Foyle, the Faughan, or the Roe, and that is what is called Magilligan Rock. At a distance it resembles two steps or terraces, and presents the appearance of a single rock, but when you come to close quarters you find it to be part of the basaltic mountain called Benevenagh. The next thing here which would attract attention is the remarkable regularity of the face of the basalt. The rocks curve and wind about from Downhill to Larganteagh in a manner which forcibly reminds one of a coast line. Up in the higher part, near Duncroon, I searched for marine shell, but found

none; but at the base of the mountain, and even as far inland as Bovevagh, marine shells are dug up in great quantities, which plainly enough indicate that this basin was formerly covered by the sea. After having carefully examined the physical geology of this part of the country, I came to the conclusion that the valley of the Foyle was never entirely roofed over with basalt, as some geologists suppose. You will observe that the River Roe forms a sort of rough natural boundary between the Palæozoic and the newer formations. The ancient sea shore must have trended from above Bovevagh, along the left bank of the Roe, to near Limavady, from thence past Eglinton to the "foot" of the Faughan, and from Culmore to Greencastle, as at present. You also see that the basalt is spread over the chalk, and as we know that the chalk was formed under the sea, we may reasonably conclude that all the country from the Roe to near Carrickfergus was submerged at the time of the volcanic eruption in the North of Ireland. After the bulk of the volcanic rocks had been spread over the counties of Derry and Antrim, and before the volcanic disturbances had ceased, the older land which connected Ireland and Scotland must have subsided. The bed of the Foyle was slightly elevated at the time of these eruptions, but, being almost outside of the upheaving force, its basin was not much changed. My reason for stating that the channel between Scotland and Ireland must have subsided at this time is that the basalt, the chalk, and the clay all dip towards the sea at a small angle. I did not quite satisfy myself on this point, but my attention was called to it by reading a passage in "Sampson's Statistical Survey of the County," in which he says, referring to a bed of clay on which the chalk rests: "It dips with the lime under the sea near Downhill; at Benbradagh it rises with the

lime nearly to the summit of the mountain." There is no doubt that the same force that caused the upheaval of the basin of the Foyle and the counties of Derry and Antrim also caused the channel to sink. The glens which separate Benevenagh from Kedy, and Kedy from Donald's Hill are the result of subaërial denudation. The country between Coleraine and Swatragh has all been overspread with igneous rocks, but a great body of water must have swept over it from the west, as we find quantities of quartz, schist, and granite pebbles on the surface, and the stone at Ballyclough must have travelled or been carried by ice from the western side of the county. I visited Lough Feagh, which lies between Slieve Gallion and the Fir Mountains. How did the lake come to be here? is about the first question one would ask oneself. It stretches for more than a mile in length, and half-a-mile in breadth, and the peculiar state of the weather made it look much larger. I must say that for the first time I saw the force of Professor Ramsey's theory of the formation of lake basins. Situated as it is so much above sea level, and in such a position, we are naturally puzzled as to its origin. Slieve Gallion, or what may be taken as a continuation of it, slopes down to its north and north-east sides, and on the Tyrone side we have the Fir Mountains hemming it it in. Scattered over these mountains, and all along the Tyrone side, we find enormous blocks of granite. Perhaps I should say syenitic granite, because I noticed, besides quartz, felspar, and mica, an ingredient which I took to be hornblende, in addition to iron pyrites, which is very distinctly seen. These huge blocks are tossed promiscuously over the drift, some of them have sunk a few feet in it, but we see that they were dropped after the *drift had* been deposited. We know that the parent rock

from which these boulders were broken off is situated on Slieve Gallion, and that they must have travelled from there over Mobuy, or the "Yellow Plain," and thence across the lough to these mountains. Now, as some of these blocks measure from 500 to 800 cubic feet, or even more, we at once see that no known power except ice could have transported them. Between Draperstown and Feeny we have splendid examples of subaërial denudation. At Lagnapaiste, or the "Hole of the Beast," there is a very pretty waterfall, caused by the outcrop of the schist. At this place we again find our matter-of-fact geology stepping in and spoiling a fine legend. As I have already explained, the pool is called the "Hole of the Beast." From this diagram you will see that another small stream flows into the Owen Reagh, or "Grey River," a little below Lagnapaiste. At the time the Drift was deposited, the meeting of two bodies of water here caused an eddy, and piled up this little gravel hill. At Lagnapaiste, Drumslieve, and Streeve we have nothing but Palæozoic and Post-tertiary rocks, the former dipping south-west, west, and north-west; whereas, if we draw a line from Knockan Bridge to Carric on the one side, and from Carric to Donald's Hill and along the valley of the Roe to a little beyond Dungiven on the other side, we have the Post-tertiary, Cainozoic, Mesozoic, and Palæozoic all represented. At Raliagh, and extending west and north-west, the secondary rocks rest unconformably on the schist, and dip in an opposite direction. If the Coal-measures have not been denuded previous to the deposition of the newer rocks, we might calculate with tolerable certainty on finding coal in this basin. There is also a natural basin near Limavady, where coal might be looked for. I will not ask you to accompany me to the top of Sawel, which might be considered the best

proof of the ice age in this county. Dart, or the "Lump," is merely a continuation of Sawel, and presents a bold face to the west. You will hardly meet with anything but schist or limestone until you arrive at Altahoney, where there is a bed of very fine slate, much used for flags and slabs. Up the glen, on to Donemana, limestone occasionally crops out. When we arrive at Donemana we are greatly struck with the gigantic scale on which Nature has sculptured the country. Here, in Altnachree Glen, we see the tremendous force which the surface water exercised. The current from this glen and the current from the glen below Benone met, and so formed Leitrim, or the "Round Hill." Indeed, all the gravel hills in the neighbourhood were formed from the matter brought down from the higher lands at the close of the Glacial Period. In the Bond's Glen we have some rocks which show the force of water in opposition to ice. At the breaking up of the ice, or after that period, an immense body of water must have swept through this glen with irresistible force towards the Faughan. Near Lackagh, or the "Stone Field," we see the rocks standing out in the glen as if the torrent had but swept down yesterday. When we reach Ardground we see an immense block of limestone or hornblende standing in the middle of the glen, and known as the Giant's Grave. It bears a striking resemblance to what the French call *roches moutonnees*. At Ballyarton Bridge the slate or shale is well exposed by a road cutting, and rests unconformably on the schist beneath it. I intended to make a drawing of an alteration in the course of Burn Tollet, in addition to that noticed by Portlock, and also a very considerable alteration in the course of the Faughan, but time did not permit me. The Faughan at one time flowed about fifty yards in the field below the residence

of Hugh Lyle, Esq., and, passing over its present bed, it flowed close under the the cliffs which skirt the orchard of James Acheson Lyle, Esq. It continued its course on to what was known as the Puddle Green, in the townland of Crossballycormick, so that formerly nearly all the fine meadows on the right bank were on the Goshedun and Knockbrack side of the river. I meant also to refer to my rambles in Donegal, but time will only permit me to touch on one point which is of some importance—viz., that the whole of the west and north-west of this county appears to be sinking. A few years ago I took an active interest in the Irish fisheries, and in order to inform myself on this subject I visited various stations along this coast, and and it then appeared to me that the coast line was sinking. Last year I had a communication from William Harte, Esq., C.E., in which he states that the coast is *now* sinking, and his word must carry very considerable weight, as there is no one in the North of Ireland better qualified to give an opinion on this subject.

"GLACIAL STRIATIONS AT LITTLE CROSBY."

By T. Mellard Reade, C.E., F.G.S.

At Little Crosby, just north of the village, is a large quarry in the Lower Keuper Sandstone. The Hall at Little Crosby, and the Roman Catholic Church, is built of this stone, and I am told it has been used in some of the Liverpool buildings. Be that as it may, it is but little used now, excepting by the owner, Col. Blundell, for purely estate work. The quarry is nearly overgrown with gorse, which has taken possession of the rubbish heaps; and I think those who wish to know how soil is

formed cannot do better than study a disused quarry, where the artificial disintegration of the rocks brings the process before us more rapidly than Nature does, if left to herself. Nor is an old quarry of less interest to the sketcher and lover of the picturesque than to the geologist; but I feel I am digressing as an artist, so must return to the present object of my communication, viz.: the marks of Glacial action which I have discovered.

Strange to say, I have visited the quarry for the last ten years, and generally have looked round to see if any striations were to be discerned, but, until lately, without avail. The top rock is of a very shelly or shaley nature generally, unfitted to retain or even to receive groovings. A short time since I observed on the surface of some quarried blocks, unmistakable signs of glaciation. I could not, however, get the direction of the markings, as none of them were to be found *in situ*. At the first opportunity I met the quarryman on the ground, and he showed me from whence the blocks had come. The rock had been cut back to the boundary wall of the quarry. I at once arranged with him to bare the rock in the farmyard on the other side of the wall, and, on next visiting the spot, was pleased to find the striations visible. The rock was covered with about two feet of soil, its surface rubbed smooth in the usual way, and the striations pointing 22° W. of N., or nearly magnetic North.

Some time since I communicated to the Society the discovery of Glacial markings opposite the Police Station in Great Crosby. The direction in that case was 40° W. of N., or 18° variation from those at Little Crosby, which are almost exactly parallel with the set of the striations I discovered at Miller's Bridge, which are described in our Proceedings.

No better example of the universality of these markings could be found than those I have just described at Little Crosby; for, as far as we can see, where they occur is the only bit of top rock in the quarry fitted to receive them, and there, as usual, we find them.

If I may be allowed to append a moral, I think my little story shows the necessity for constant watchfulness on the part of the geologist, if he wishes to wrest any fact, however small, from oblivion.

DECEMBER 12TH, 1876.

THE PRESIDENT, HUGH F. HALL, F.G.S., in the Chair.

JOHN T. LEWIS, B.A., was elected an Ordinary Member.

The following communication was read:—

SOME NOTES ON SURFACE SCULPTURE,

BY HENRY C. BEASLEY.

THE object of this paper was to draw attention to the phenomena to be observed upon Wansfell, a mountain at the head of Windermere, as illustrating the great variety of causes that have given its present outline to the earth's surface.

Wansfell is a pointed ridge rising to a height of 1,580 feet, and is composed of the members of the Coniston series dipping a little to the east of south at an angle of 30°, and resting upon the Green Slates and Porphyries which compose the summit and the north-eastern slope. The direction of the ridge corresponds with the strike of the

beds. The author pointed out how Plutonic agencies originally gave the strata their high inclination, without which no amount of denudation could have formed a mountain of this contour. He then suggested the probability of a comparatively level surface of marine denudation having been formed at a relatively higher level than the present summit (of which, of course, no trace is left) on which rain and running water eroded the main lines of the present valley system of the district. The action of rain and frost, as exhibited upon the peaked summit of the mountain were then described, and the Glacial groovings and rounding of the rocks on the shoulder of the mountain at an elevation of about 1,000 feet.

The hollow on the S.E. side was ascribed to the action of running water originally, its outline having since been rounded by Glacial action, and the valley again seamed with steep ravines by the present streams, whose action in cutting valleys along the strike of the rocks is very clearly exhibited. It was then shown how a considerable delta was being formed of the *débris* from the valley above, where the stream entered the lake close to Lowwood Hotel. Here all the phenomena of a large river might be seen on a small scale.

The tract of country extending eastward from Bideford Bay and drained by the Torridge and its tributaries, was then described. The strata there are also inclined at a high angle, and an ancient plain of marine denudation is still discernible, at a height of about 400 feet above the sea level into which the rivers have cut deep and wide valleys, separated by rounded or flat-topped hills. The absence of pointed ridges here was explained as due to the comparatively short time during which

denudation had been going on here, and also to the influence of a climate particularly favourable to the rapid and luxurious growth of vegetation, which protects the hills from the washing effect of rain. It was pointed out that, although the sides of the valleys were very steep, as far as the author had been able to observe there was not a single bare cliff in the district, with the exception of some of the sea cliffs. The effect of vegetation on the contour of the land was particularly insisted on, and attention was drawn to the Ill-bell range of mountains, a few miles to the east of Windermere. This ridge runs in a direction at right angles to the out-crop of the strata, so that the geological structure of both sides is exactly similar. The slope open to the south and west winds and enjoying a larger share of sunshine presents tolerably even grassy slope, whilst the other is bare and precipitous, and rapidly wearing away under the influence of frost and rain.

JANUARY 9TH, 1877.

THE PRESIDENT, HUGH F. HALL, F.G.S., in the Chair.

The following communication was read:—

THE CONDITIONS EXISTING DURING THE GLACIAL PERIOD; WITH AN ACCOUNT OF THE GLACIAL DEPOSITS IN THE VALLEY BETWEEN TRANMERE AND OXTON.

BY CHARLES RICKETTS, M.D., F.G.S.

THE examination only of the beds, or of the materials which constitute the major portion of any geological formation, will rarely enable us satisfactorily to deter-

mine the circumstances under which deposits have been laid down, the manner in which they have originated, or from what sources derived. Due consideration must certainly be given to the evidences afforded by those sediments which have a similar character over large areas; but it is necessary that an equal regard be given to the deposits which in different localities are situated at and form their base; the contour of the underlying rocks must also be taken into consideration before a satisfactory elucidation of the problem can be discovered.

When attention had been so far directed to the Boulder-clay formation that the erratic pebbles, so many of which have all irregularities ground away and their surfaces rendered smooth, often grooved and striated, had been in some instances traced to certain known localities, it was at first considered that not only had these ice-marked boulders been floated on floes or bergs, which on melting dropped them in the localities where they are found, but also that the whole of the clay in which they are embedded had been conveyed in a similar manner. This idea was entirely set aside when, in many places in the valley of the Mersey, on the removal of this clay, the underlying rock-surfaces were, over large areas, discovered to be smoothed and striated, the grooves being so regular in direction that, by no possibility, could the opinion be maintained that these striations were caused by the grounding of icebergs; but, as they correspond entirely with markings on rock-surfaces formed by glaciers now existing, their origin can only be attributed to a similar action; and there is no other known agency by which they could be produced. The inference almost necessarily followed that, as streams issuing from beneath glaciers are always

highly surcharged with mud, the clay itself deposited in this glacial sea had resulted from the degradation of rocks in the district, as a consequence of the eroding action of such glaciers in their passage down the valleys, which terminated in what is now the Bay of Liverpool.

Of the possibility that such was the method of the production of this clay, convincing proof has been given by the eminent Arctic observer, Dr. Robert Brown, F.R.G.S. He shewed that in Greenland a clay, so similar that no appreciable difference can be found between it and the brick-clay or fossiliferous Boulder-clay, is formed as a deposit from the waters which issue from beneath the Glaciers as Sub-glacial rivers, thickly loaded with the mud resulting from the grinding of the Glaciers on the infrajacent rocks. These Sub-glacial rivers pour out from beneath the Glacier, whether it lies at the sea or in a valley; their stream flows in a torrent the whole year round, and, reaching the sea, discolours the water for miles, and finally deposits on the bottom a thick coating of impalpable powder.*

Much attention has been directed to the consideration of the causes which induced a climate of such intensity as to cover with a mantle of perennial snow not merely Britain, but also, and at the same time, immense districts now amongst the most fertile in the Northern Hemisphere. Some, without, as I think, any sufficient evidence, imagine that the area surrounding the South Pole is entirely covered with a thick capping of ice; that the whole of this supposed continent, about 2,800 miles in diameter, is covered with one continuous sheet of ice, gradually thickening from its edge to its centre; and it

* "Physics of Arctic Ice," by Robert Brown, Ph. D., F.R.G.S.—*Quart. Journ. Geol. Soc.*, vol. xxvi, p. 681.

is presumed that twelve miles would be a moderate amount to ascribe to the thickness of this cap at the Pole. They overlook the effects of intense cold in precipitating moisture contained in the atmosphere. With a winter of such severity as occurs within the Antarctic Circle, the whole of the water would be removed before the winds could pass over a radius of 1,400 miles. Certainly there would be no snow covering the ground within many degrees of the Pole which would not be removed by the heat of the sun during the long day of summer.* The existence of such a monstrous ice-cap at the South Pole having been taken for granted, it has been imagined that, during the Glacial Period, the whole of the waters of the Arctic Ocean formed one mass of ice, with snow thickly piled upon it, and on the larger portion of the land situated in the Northern Hemisphere. Such an accumulation of snow as is here supposed is not only at variance with physical laws at present existing, but, if it possessed the motion which Glaciers have, would have entirely swept away the remains of the Mammoth, Woolly-haired Rhinoceros, and other animals so commonly found in Siberia and the northern parts of America.

Appearances have been observed in Central America which have been *supposed* to indicate the former existence of Glaciers within 13° of the Equator, and it has been considered that these "covered all the higher ranges, and descended in great Glaciers to at least as low as the

* Captain Nares reports that, in the Arctic Expedition, on June 13th and 21st, a thermometer, with a blackened bulb *in vacuo*, exposed to the sun's rays, registered + 128° and + 129° Fahr. respectively; the temperature of the earth's surface at the time being + 27°, and of the air + 34°.

line of country now standing at two thousand feet above the sea, and probably much lower."* Such a condition has been referred to what is known as the Glacial Period. Mr. Belt's examination of the deposits on which he founds this opinion was too cursory, and the inferences are so entirely opposed to the physical conditions now existing there, for them to be readily accepted without further examination. The determination must be left to the investigation of future observers.

Such an hypothesis is incompatible with observations made by the United States Geological Survey of Colorado.† In the district of the Upper Arkansas, about the latitude of 39° N., where "the general elevation of the Sawatch Range for 60 or 80 miles is 13,000 or 14,000 feet above the sea," and that of the bed of the River Arkansas from about 7,500 to 9,800 feet, there is abundant evidence of Glacier erosion, and "the sides of the mountains are worn smoothly and exhibit signs of Glacial action to the height of at least 1,500 feet above the valley," an immense amount of moraine *débris* resulting from it remaining unremoved; whilst about 80 miles to the east, upon the same parallel of latitude, near Colorado City, situated at a height of 6,000 feet in the river-bed, and at about 7,500 feet at the water-divide, so far from there being this evidence of the previous existence of Glaciers, there are most remarkable examples of *sub-aërial* erosion—massive Triassic (?) Sandstones, fifty feet and upwards in height, weathered into the most fantastic shapes, some of which are isolated monoliths; amongst them is a magnificent natural obelisk, 250 feet

* "The Naturalist in Nicaragua," by Thomas Belt, F.G.S.; p. 262.

† "Report of the United States Geological and Geographical Survey of Colorado, &c., for 1874."

high, called the "Cathedral Rock," situated in the "Garden of the Gods," Colorado; (Fig. 6.) whilst in rocks of later formation are numerous peculiar columns in "Monument Park." (Fig. 7.) Any of these would have been broken away by the pressure of an accumulation of snow persisting during comparatively a few years.

If, by any possibility, such a climate could have existed in Equatorial regions, there must necessarily at the same time have been a period of most intense cold during winter in higher latitudes; but, with such conditions, the atmosphere could not be supplied with watery vapour, as it is now, more or less directly from Equatorial waters; so that there would be but little contained in it to be precipitated in more northern climes, and therefore Glaciers could not exist there. It would be as impossible for there to have been the system of Glaciers which *are known* to have existed in North America and in Europe, as it would be for a steam engine to be set in motion without a fire underneath the boiler. "The lessening of the sun's heat would infallibly diminish the quantity of aqueous vapour, and thus cut off the Glaciers at their source." *

Respecting the conditions which prevailed in our own country, it has been assumed that "the Irish Sea was filled with an immense Glacier moving southwards, having a thickness of at least 2,000 feet; that it butted against the Welsh mountains, and, dividing, one part pushed *up* the valleys of the Mersey and Dee, and through what has been called the Straits of Malvern." †

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* "The Forms of Water," by John Tyndall, LL.D., F.R.S., p. 21.

† "The Climate of the Glacial Period," by Thomas Belt, F.G.S. *Quarterly Journal of Science*, Oct., 1874.

2.

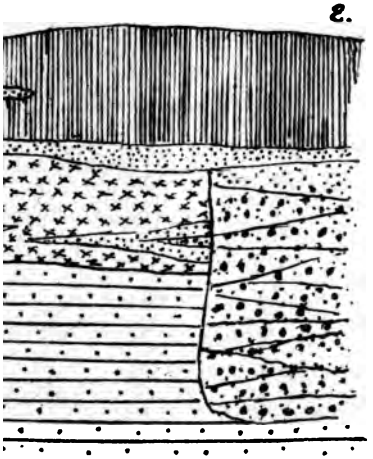
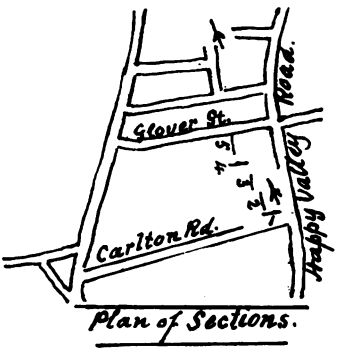


Fig. 2.



N.

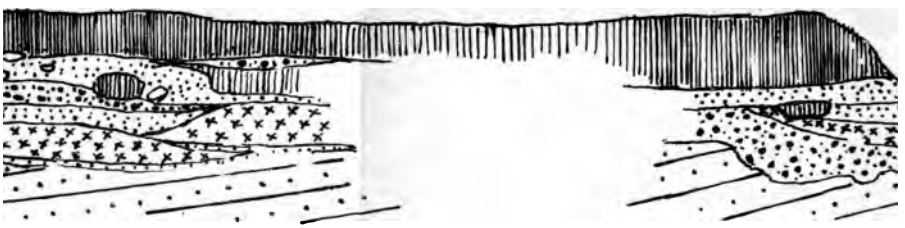


Fig. 3.

6.



Rock.' Colorado.
height 250 feet.

S. N.

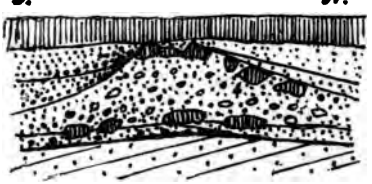
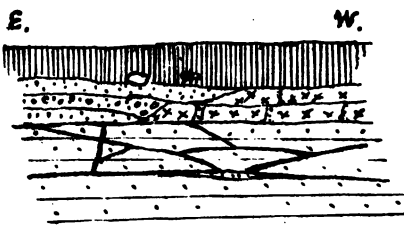
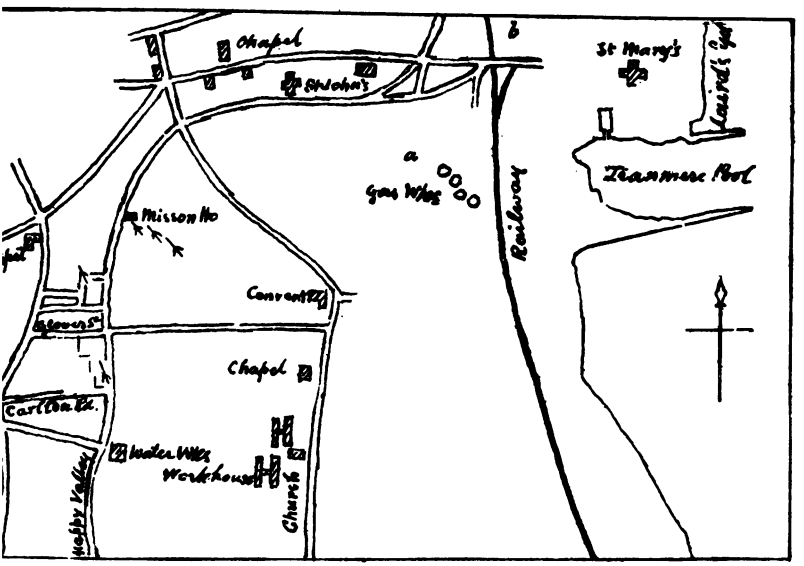


Fig. 4.

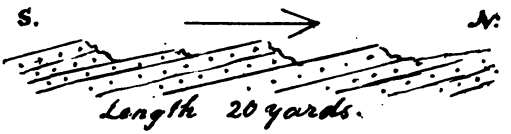
E. W.





Scale - 3 inches to a Mile.

Fig. 5.



Length 20 yards.

g. 7.



numont Park, Colorado.

Boulder Clay
Clay blocks
Boulders
Pebbles & Sand
Sand
Moraine Sand
Trias
Sections 1 to 4 = 1/10 in. to foot
Seemarks → Locality shown by the angle

Prof. Ramsay, in a paper read before the Geological Society last year,* without recognising a polar ice-cap, attributes the glaciation of Anglesey to a vast mass of ice moving southwards from Cumberland, reinforced by ice-streams that came from the Mountains of Carrick, in the south of Scotland, and perhaps even from the basin of the Clyde. He considers that this enormous Glacier overspread the region now occupied by the low ground of Anglesey, and went to some unknown distance beyond. There are exposures in Anglesey which afford evidence that the *latest* glaciation of the island did not result from such a system of Glaciers as has been supposed. Thus in the circumscribed area of Serpentine, lying a little south of Valley Station, on the Holyhead Railway, there is exposed a smooth and striated surface covered with a moraine *débris*, so completely derived from the immediate locality that it *entirely* consists of angular fragments of the Serpentine itself; and at Llanerchymedd, on the Anglesey Central Railway, the striæ on a boss of rock situated close to the station have a direction *towards* S. 10° W., varying, as they curve round it, to S. 20° W. Professor Ramsay remarks that the Glacial striæ of the Island of Anglesey run generally in a direction from 30° to 40° west of south, and that "these striations point directly to the mountains of Cumberland;" but this is also very nearly the same direction as that of the Pre-Carboniferous valley, in which, on its subsidence, the Carboniferous Limestone and Millstone Grit were deposited; so that the Glaciers flowed in channels, which had been marked out by the comparative hardness of different rocks that have existed from Palæozoic times.

Observations made in the valley of the Mersey are altogether at variance with the idea of such an enormous

* "How Anglesey Became an Island," by Professor A. C. Ramsay, F.R.S., *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 116.

ice-sheet as has been supposed. There are abundant evidences that it and its tributaries were filled with Glaciers, not progressing from an immense accumulation in the north, but formed by the snowfall in the respective valleys, being of such an extent only as might reasonably be considered due to the amount of deposition on their water-slopes. In numerous localities around Liverpool the Triassic rocks, where protected from the action of the weather by the overlying Boulder clay, and sometimes by beds of sand, on the removal of these accumulations, have displayed smoothed and striated surfaces, the direction of the striæ varying in different places; but, so far as I have observed, always taking a direction similar, or nearly so, to that of the valleys in which they are situated. Besides these striated surfaces there are other evidences of the local action of Glaciers. I have seen beneath the Boulder-clay, in the section exposed in the making of the Huyton and St. Helens Railway, and near Whiston, accumulations of unstratified materials, derived from the adjacent rocks, consisting of loose sand where there are Triassic rocks; of grey mud, containing fragments of coal, where there are Coal-measures. Combining these collections with the striated rock-surfaces, they can only be considered as moraine *débris*.

In Happy Valley, the tributary of the Mersey which forms the division between Oxton and Tranmere, and terminates at Tranmere Pool, the removal of the Boulder-clay has revealed several examples of these glaciated surfaces, whilst the excavation from time to time of those deposits which in the bottom of the valley overlie the sandstone, have afforded sections, limited in area, but not the less instructive in assisting to determine the circumstances under which the glaciation of the rocks

and the accumulations of sand and gravel in the bottom of the valley have taken place; whilst the consideration of the whole will assist in forming an opinion respecting the manner in which the Boulder-clay has been deposited, not only here, but likewise in the surrounding districts.

There is now visible, close to the Presbyterian Mission House, grooves deeply cut in the Triassic sandstone, sufficiently large to receive a man's finger; and another striated surface is situated in the adjoining field at a very short distance from a pond, though superficial, these striæ are very distinct. A few years ago an example might be seen at the further end of the field, but, being in a soft sandstone, the grooves have now been entirely erased by weathering. In these instances the striæ have a direction of N. 40 W. There is another, now covered over, higher up the valley, in the unfinished street, nearly opposite a boss of current bedded sandstone, cut through in making the Happy Valley road, from which it is sixty yards distant; the direction of the striæ is due magnetic north. A small surface, about a yard in length and a foot and a half in breadth, is exposed close to the road, about seventy paces from Carlton Road, the striations being placed thickly together, and having a direction of N. 20° W. (See sketch Map.) *

Between Glover Street and Carlton Road the Triassic strata dip up the valley at an angle of 10°. As a consequence, at the basset edges the beds appear as if the rock has been broken off in the opposite direction in a steplike manner, as represented in the diagram Fig. 5; the hollows thus formed are filled with sand and gravel, the whole being covered with Boulder-clay.

* Mr. Bostock was the first who observed striated surfaces in Happy Valley.

In one of the sections (Fig. 4) the fracture appears to have progressed to the extent of cracking the upper portion of the bed only, slightly displacing the rock, and forming fissures in various directions, from half an inch to an inch and a half in width, which have been filled with sand and clay, having minute erratic pebbles intermingled.

On the bottom, and extending somewhat up the flanks of the valley, there are, underlying the Boulder-clay, beds of loose materials, sometimes of sand and fragments of sandstone derived from the immediate neighbourhood, not distributed by the action of water nor mixed with materials derived from distant sources. This I will designate *moraine*-formation; also similar sands which have been re-distributed, some of which contain an abundance of pebbles, sometimes fine, in other places larger, similar in kind to the erratics which occur in the Boulder-clay. These beds of drifted materials, as well as the underlying Triassic Sandstone, have at different times been excavated in various places, sometimes as areas for building, at others in order to make use of them for building materials. The most interesting sections are situated between Glover Street and Carlton Road. (A record of each exposure should be made at the time, lest it suffer damage from the weather, or be covered up in subsequent operations by the workmen.) At the corner of Carlton Road the sandstone is covered with an accumulation of yellow sand, so little altered in appearance from the underlying rock that, were it not for the occurrence of thin bands of brown sand and of patches of sand containing erratic pebbles, it might, without special attention, be easily mistaken for the soft Triassic Sandstone *in situ*. In some places a band of this pebbly sand separates this

moraine-like accumulation from the sandstone; in others the moraine itself is divided by this washed sand, whilst in this locality a thin layer of it separates the moraine from the Boulder-clay. (Figs. 1 and 2.)

Two or three years ago an excavation was made in irregularly stratified beds of gravel and sand containing small rolled fragments of shells, accumulated in a channel nine or ten feet wide, which had cut through a moraine accumulation and the Triassic Sandstone to a depth of eight or nine feet. The sides of the moraine and also of the sandstone were perpendicular, the latter even overhanging at one part. (Fig. 1.) There are other places where the sandstone has been hollowed out and worn as if by streams of water, the channels having been subsequently filled with gravel and sand (as in Fig. 2).

"Sub-glacial rivers are familiar in all alpine countries, and in Greenland pour out from beneath the Glacier, whether it lies at the *sea* or in a valley, in summer and winter."* It appears most in accordance with concurrent phenomena, to attribute the formation of these channels to the action of such streams issuing from beneath a Glacier extended some distance into the sea. The striæ left on the Triassic rocks and the moraine sand indicate that a Glacier existed immediately before the excavation; whilst the thin beds of pebbly sand interbedded with the moraine show that, at the time of their occurrence, the latter was beneath the water; so also do the perpendicular walls, especially of the loose sand, which, had it experienced a few days of subaërial exposure, would have been reduced to an acute angle, or washed away entirely.

Not a very long time could have elapsed—not long enough for tidal or other currents to remove the moraine

*Dr. R. Brown, *Quart. Journ. Geol. Soc.*, vol. xxvi, p. 681.

accumulation—before the Sub-Glacier stream ceased to flow through this channel with sufficient force to counteract the action of the sea. The Glacier must have receded, possibly by its diminution; but, as the period of intense cold continued long afterward, it may quite as probably have been from persistent depression of the land, causing a greater depth of water, by which a Glacier of the same thickness would be floated and broken off higher up the valley. At all events, the force of the current issuing from beneath the ice was so lessened that it no longer kept for itself this passage, but the channel became filled up in the manner described.

On the bottom of the valley, between Carlton Road and Glover Street, and somewhat up its western flank, the Triassic Sandstone and the moraine accumulations, where they exist, are covered with beds, sometimes of sand only, sometimes of sand mixed with small fragments of rock foreign to the district, such as are so abundant in the Boulder-clay, but never, so far as I have observed, having any striæ upon them; there are also beds of gravel, chiefly consisting of these erratic pebbles of various sizes, occasionally containing large boulders of Granite, Trappean, and other rocks, as well as fragments of Triassic Sandstone, and sometimes blocks of the Boulder-clay itself. (Figs. 2–4.) The beds of sand are also sometimes interstratified with thin bands of this clay. In different beds there are also a considerable number of fragments of marine shells, so broken and rounded by attrition as not to admit of identification. The area in which the individual beds retain the same character is very limited; their materials have been repeatedly heaped together, portions have been again removed, to be afterwards overlaid by others in which the deposit differs somewhat in composition; these processes have been repeated again and again.

Some years ago there were exposed at the lower part of the valley, near the Gas-works (*a* on Map), beds of sand and small erratic pebbles, containing an abundance of shells, mostly comminuted, but many were perfect, or nearly so; the species of these have been determined by Mr. Morton.* These shells could not have lived at the place where they were found, but must have drifted from a locality situated at a comparatively short distance, and where there must have been conditions suitable for their existence; but as yet I am not aware that any beds referable to the Glacial Period have been discovered, with similar shells in the place where they had existed.

There was at first considerable difficulty in making a reasonable explanation of the presence, in the Drift gravel and sand, of the blocks or pebbles of Boulder-clay (Figs. 2, 3); they are angular in form, and therefore had not been exposed to attrition, or rolled, in the same manner as are the balls of clay so commonly found upon our shore. In accounting for them, circumstances which are known to have been then existing must be taken into consideration: that a Glacier extended into the sea within a few score of yards of this place; that the bay was closely packed with innumerable ice-bergs and floes; that the Boulder-clay, with its countless ice-borne erratics, was after a short time deposited above the sand and gravels in which these blocks lie; and that the deposition of this clay must have been in progress at the same time near the mouth of the Mersey. Regard must also be paid to the recorded effects of Glaciers in the Arctic Regions which appear somewhat similar. Dr. Brown remarks that "if a

* "Proceedings of the Liverpool Geological Society," Session 1871-72, p. 92.—Excavations have very lately been made near the Gas-works, in thick beds of similar sand; but only fragments of shells were found, all very much comminuted.

berg grounds on a bank or shoal, or in any water not deep enough for its huge bulk to float in, it will often bring up from the bottom boulders, gravel, &c., deposited by former bergs," and "the clayey bottoms of shallow inlets will be grooved and torn up by grounding bergs."* I think it is more than probable that icebergs may have grounded upon some lately deposited bed of Boulder-clay, and again floating off, bore away portions of it, and drifting to this locality, on melting, dropped their load here. If this is the true explanation of the origin of these blocks, the production of the thin and localised bands of clay before alluded to may have arisen from the same cause; some of these blocks after they have fallen down may have become dissolved, and thus spread over a more extended surface.

Lower down the valley, from about the Mission House to the Gas-works, beds of sand which have been exposed beneath the Boulder-clay are remarkably free from erratics, excepting those of a minute size, which are there in abundance. The same may be considered to be the general condition of those cut through near Grange Lane in making the new railway tunnel (*b* on map), though some larger ones were thrown out amongst the materials removed. So great a difference between these beds and those situated higher up the valley, leads to the inference that each had been formed under somewhat different conditions; there must, in the former instance, have been some impediment to Glaciers, laden with erratics, floating over the immediate locality, otherwise there would not be this absence of large pebbles; the smaller ones are such as might have been brought from a short distance by currents, and thus became mingled with sand derived from the disintegration of the Trias.

* *Quart. Journ. Geol. Soc.*, vol. xxvi, pp. 687 and 690.

Mr. Morton has described these "Lower Drift Sands and Gravels" chiefly as they occur beneath the Boulder-clay in the cliffs forming the boundaries of the Mersey:—"The beds of gravel are of limited extent—mere nests or patches distributed through the sandy strata—frequently containing fragments of shells, and sometimes perfect specimens;" and he considers that "the deposit has probably originated from the disintegration of the Triassic rocks, immediately before the deposition of the Boulder-clay."* The late Mr. John Cunningham C.E., F.G.S., found beds of loose sands and gravels, with fragments of shells, in sinking for water close to Wallasey Pool; these loose strata proved so great an impediment that he was obliged to sink the well in another place. Mr. Bostock found the same in boring in the valley of the Fender on the Upton Road to determine the character of the underlying rocks. He has also supplied other localities, where the same have been met with in borings and well-sinkings, which Mr. T. M. Reade, F.G.S., has recorded in our Proceedings, with many that have occurred to himself and friends.† These gravels and sands appear to occur either on the bottom of valleys which had lately been filled with Glaciers or a little way up their flanks.

My observations lead me to the conclusion that 225 feet, or it may be something less, was the greatest thickness of the Mersey Glacier in mid-channel. In excavating for the foundations of a building connected with the Birkenhead School, at the height of 200 feet above the rocky bed of the Mersey, there was

* "Geology of the Country around Liverpool," by G. H. Morton, F.G.S., p. 42.

† "The Buried Valley of the Mersey."—Proceedings of the Liverpool Geological Society; Session 1872-73, p. 42.

exposed, in an accumulation of moraine breccia, consisting of angular fragments of sandstone and loose sand, a hollow place or channel about a yard and a half wide and a foot and a half thick, filled with a whitish clay, such as is commonly found as balls or pebbles in the Keuper Sandstone or as beds interstratified with the sandstone; both the *débris* and the clay are covered with Boulder-clay. This moraine covers a considerable surface, both below and above the schoolhouse, and has been derived from the sandstone in the immediate vicinity. It does not appear possible that the Glacier which originated it could have formed an integral part of that which filled the valley of the Mersey, and, extending over the present site of Birkenhead, passed through the gorge between Bidston Hill and Wallasey.* Had such been the case, everything must have been swept onward in its passage towards the sea. It is more probable that this *débris* may be ascribed to the effects of an accumulation of snow on the land between it and the water-parting, causing the degradation of the rocks, and by its movement carrying down the disintegrated materials to near the sea-level at that time. The limited deposit of clay would have originated from percolation of water through this moraine, washing out from the disintegrated sandstone of the Keuper the clay it contains in such abundance; and this settled in this hollow or pool, separated in some way from the waters of the ocean. If such was the cause of its formation, or if the Glacier of the Mersey, by floating, was separated from that upon the summit of this ridge, the greatest thickness of the the Glacier could by no possibility be greater than the amount specified, being the height of the locality above

* "Glacial Phenomena of Western Lancashire and Cheshire," by C. E. De Rance, F.G.S.—*Quart. Journ. Geol. Soc.*, vol. xxvi., p. 652.

the rocky bed of the Estuary, with the addition of one-eighth for flotation. It is desirable for the confirmation or refutation of this suggestion that advantage be taken of any opportunity afforded by excavations on either side of the Mersey, at heights from 120 to 160 feet above the sea level.

The Boulder-clay containing abundance of ice-marked pebbles derived from distant sources* is so well known that there is no necessity to direct attention to its characteristics further than to notice the occasional occurrence in it of flints. They have been observed but seldom by Mr. C. E. de Rance, F.G.S., of H.M. Geological Survey; more frequently by Mr. D. Mackintosh, F.G.S., and by others. Though not common, these flints may generally be found after a prolonged search, but sometimes several are situated close together. I found five or six thus placed off the Red Noses, New Brighton, and about the same number within an area of a square yard on a bank by the roadside at Neston. Mr. A. Strahan, F.G.S., of H.M. Geological Survey, told me that he also has met with several near together.

I have met with flints in almost every brickfield in the Birkenhead district, but some from Happy Valley are so remarkable as to deserve particular notice. The largest specimen has a portion split off at one end, and appears much weathered; projections on its rounded end are abraded, not smoothed as flints usually are which have been exposed to grinding action on the shore, but as if little fragments had been chipped out by forcible

* Since the reading of this paper, I have found a very large number of erratic boulders, some of which, sculptured by the action of the weather, bear no evidences of glaciation or rolling; the others, with a greater or less amount of ice-polishing and scratching, are also distinctly weathered.

pressure against some hard substance. This erosion does not affect even superficial depressions on the surface. A fragment of another has been exposed to the same chipping, and has also several small patches rubbed smooth and polished; one of these places is also striated. This and another of about the same size have been so altered by weathering that they are white throughout their whole substance. Another has a fragment of white limestone attached. This has a granular appearance; but, though thus altered, its hardness is such that it can only be referred to the Chalk or White Limestone of Antrim. I have also obtained a piece of similar limestone granular upon one side, whilst the other is smoothly polished and striated. The flints, weathered but not waterworn, coincide with those so abundant on the eroded surface of the Chalk of the North of Ireland, where they are overlaid by Basalt.*

Marine shells, all of littoral species, are found, but not frequently, in the Boulder-clay. Excepting *Turritella communis* and a solitary specimen of *Litorina litorea*, they are very seldom in a perfect state, being more or less broken, generally into small fragments. Embedded in a soft matrix of clay, their fractured state indicates that they have not existed where found, but have probably been conveyed and deposited in the same manner as the erratic boulders.

The smoothed surfaces of the rock, striated here and elsewhere in the general direction of the valleys, and in a similar manner to what occurs in countries where Glaciers now exist, indicate a period when here also the

* Mr. Isaac Roberts, F.G.S., possesses a specimen of flint exactly similar to those which, at Belfast, are situated in the hollows formed on the eroded surface of the Chalk, and lying immediately under, have been altered by exposure to the action of the Basalt.

valleys were filled with Glaciers and perennial snow covered the district. The loose unstratified sand which I have called 'moraine,' containing no materials foreign to the neighbouring rocks, is found in numerous places elsewhere. Combining these accumulations with the existence of Glacier markings on the rock surfaces, they can only be considered as having been derived from the grinding of Glaciers upon the rocks, and were carried forward in their progress until this *débris* has been left behind at the termini. As they have been formed at the foot of the Glacier, it follows that the Glacier must have moved *down* the valleys; and, with the occasional occurrence of interbedded bands of sand containing fragments of marine shells in connection with them, it follows that the termination of the Glacier was in the sea. These conclusions respecting the local origin of the Glacier have been confirmed by other observations; as the tributary Glacier from Tranmere meeting that from Happy Valley at an acute angle; the Triassic beds fractured off where the rock projects at Glover Street (Fig. 5); and the channels, especially the one at Carlton Road (Fig. 1), formed immediately after the recession of the Glacier.

The land during the Glacial Period must have been covered with perennial snow, and many a Glacier, filling the valleys of Cumberland, Wales, and Ireland, extended into the sea, and gave origin to bergs, numbers of which, under the influence of prevailing winds, drifted into the Bay of Liverpool and Estuary of the Mersey, and, melting, dropped their load of ice-marked pebbles; but every phenomenon is in direct antagonism to the hypothesis of a monstrous Glacier filling the Irish sea, or of one extending from the mountains of Cumberland, across the Bay of Liverpool, and over the Island of Anglesey. With such supposed barriers, no sea could have existed between

them and the mainland; none of those pebbles with which the Boulder-clay is studded could have passed over and reached the situations where they are embedded in it; least of all could those ancient Irish immigrants, the flints and pieces of Chalk from the Antrim district, have crossed such an obstruction.

That there were no powerful currents is shewn by some of those accumulations in the sea, which I have termed moraine sand, not being re distributed; by the removal of the sandy and gravelly beds being partial only; and their re-deposit, though frequently repeated, being very localised, as is shewn by the different sections, especially in the one represented in Fig. 3. Little more could have been effected by the tide than was due to its rise and fall. The bottom of this valley appears to have been somewhat deep in the water, but there must also have been an obstruction to the water rushing up and down it, constituting the ebb and flow of the tide. The presence of a Glacier within a short distance of these Drift sands and gravels, as proved by other evidence, would act as such a barrier to the ingress of the sea. So that, on that account, and the deep water occupying the Bay and Estuary, the tidal currents must have been exeedingly slight, and probably much of the erosion of these beds, and their re-distribution was due to Sub-glacier streams. The absence of stratification in the Boulder-clay is most remarkable, whether it has been deposited in what must be presumed to have been deep water, as in the bottom of the valleys, or where it has been shallow, as on their flanks and ridges. Had currents existed of even moderate force during the time it was being deposited, some re-arrangement of the sands and pebbles would have taken place, giving to it a bedded appearance. Reasons have been shewn why the rise and fall of the tide

should not have affected these deposits; but there would have been some evidence of stratification, at least in what is now higher ground, had there been such wave action as occurs now. The Boulder-clay contains in the arrangement, or, rather, want of arrangement of its innumerable ice-marked pebbles, the clearest evidence that never in these waters did wind-waves then exist. The floating ice and bergs which conveyed these pebbles must have covered the bay so entirely that, protected by an immense accumulation of pack-ice, the winds, however tempestuous, had no such effect in disturbing the water as to distribute the constituents of the Boulder-clay in a stratified manner.

In attributing the great difference of climate prior to, during, and after what is called the "Glacial Period" to astronomical causes, whether due to increase of the obliquity of the ecliptic or of the eccentricity of the earth's orbit, or to other influences, it has usually been considered that the effects produced were dependent upon a general increase in the intensity of cold only; that the more the temperature was diminished the greater would be the amount of snow precipitated, and, in the Northern Hemisphere, the farther south Glaciers extended the greater would be the snow-fall in the north.

Before intense cold could precipitate water contained in the atmosphere in the form of snow, heat at or near the Equator was required to saturate the air with this moisture. In reference to this subject, Professor Tyndall remarks:—"In this process of distillation, *heat* plays quite as necessary a part as *cold*. Before Bishop Heber could speak of 'Greenland's icy mountains,' the Equatorial ocean had to be warmed by the sun."*

* "Forms of Water," p. 21.

In passing over land surfaces, even in temperate climes, the atmosphere parts with much of its moisture. In our own island the rainfall on the east coast is only about a third of what it is upon the west, where the winds which have traversed the Atlantic first impinge upon the land.

Though in Siberia the intense cold of winter has for ages so far exceeded the warmth of summer that the ground is frozen to the depth of at least six hundred feet, yet sufficient moisture has not been retained in the air which traverses the continents of Europe or Asia to produce perennial snow; for in passing, during August, 1875, up the River Jenisei from its mouth, Professor Nordenskjold, of Sweden, "saw snow only at one place, a deep valley cleft of some fathoms extent." But the severe cold and long absence of light of the Arctic winter had not prevented the warmth of the summer's sun producing within the Arctic Circle "a vegetation remarkable for a luxuriance, to which he had seldom before seen anything corresponding. In a territory, part of which lies north of the Arctic Circle, are found the most extensive and finest forests of the Globe."* He refers to a fact which he considered improbable beforehand, that "the northern limit of many plants in Siberia is situated farther towards the north than in Sweden. It appears that the severe winter of Siberia has by no means any specially injurious influence on the vegetation of the summer." †

Compared with Greenland, no great accumulations of snow takes place in the Parry Islands, "no Glaciers of any size exist, westward of the 85th meridian of west longitude in Lancaster Sound, and no true icebergs are met with in the Great Arctic American Archipelago.

* *Nature*, vol. xiii., p. 97. † Page 275.

Here and there, in dark and sunless ravines of North Devon and Melville Island, a diminutive Glacier may be found, but it never reaches the sea so as to form icebergs."*

Reasoning from Professor Nordenskjold's report, it appears that, if there is the warmth of summer—in other words, if there is no greater amount of snow on the ground than can be readily melted by the sun's rays —no intensity of cold or absence of light in winter has the effect of preventing, even within the Arctic Circle, the growth of luxuriant vegetation. It may have been quite possible that trees and plants, as abundant as those found at Disco, Banks Land, Discovery Bay, Spitzbergen, &c., may have flourished in these latitudes during a Glacial Period affecting more southern localities; for, after passing over land covered with snow and seas filled with bergs and floes, there would remain in the air no more moisture than would supply snow readily melted when summer commenced.

On the discovery of these plant remains in these high northern latitudes, it was generally—I believe universally —considered that it would be quite impossible at the present time that vegetation, such as can be called luxuriant, could exist within the Arctic Circle. Dr. R. Brown, the chief collector of them in Greenland, says, "the very large number of species obtained from a very small space betokens a flora more tropical than temperate, for he is not aware that any similar area in Italy (with the temperature of which Dr. Heer compares the climate of Greenland at the time of their growth) produces a similar number of species. Yet the plants found are not those

* "Mc Clure's Discovery of the North-west Passage," edited by Captain Sherrard Osborn, C.B., p. 149.

of the tropics, but of temperate regions."* The information respecting the River Jenisei supplied by Professor Nordenksjold may render necessary the re-consideration of the climatic conditions under which these fossil Arctic plants flourished. But if the species are such that they could not have existed with an intense winter followed by a warm summer, such as occurs in Northern Siberia, before attributing this difference in climate to astronomical causes, it will be well to determine whether any physical change has taken place or might reasonably be supposed to have occurred which, altering the relative positions of land and water might change the direction or force of the currents of the ocean, and induce in these regions a climate comparable with that of the temperate zone. The depression of Florida below the sea level (a circumstance which occurred in the Tertiary epoch) would greatly increase the warmth of the North Atlantic Ocean. Not only would the Equatorial waters escape from the Gulf of Mexico three hundred miles further north, but they would do so in much greater volume.

In 1851 Mr. William Hopkins, F.R.S.,† then President of the Geological Society, considered the effects which various *possible* changes in the configuration of the land, during recent geological times, would have in causing alterations in temperature. Amongst others he took into consideration the hypothesis of depression of the valley of the Mississippi so as to permit the Equatorial waters to pass in that direction into the Arctic Ocean. He concluded that the Gulf Stream would lose all sensible influence on the coasts of Western Europe, but would

* "Geological Notes on the Noursoak Peninsula, Disco Island, &c." Transactions of the Geological Society of Glasgow, vol. v, part 1.

† *Quarterly Journal of the Geological Society*, vol. viii.

necessarily increase the temperature along its altered course, and especially in the cold regions of North-western America, towards the present shores of the Arctic Sea. Evidence is yet wanting of this supposed communication between the Mexican Gulf and the Arctic Ocean. The results of the examination of the Rocky Mountain district by the United States Survey indicate a period, referred to the Tertiary, when the relative conditions of land and water must have most materially modified the climate of the whole of the North American Continent. The base of the "Great Lignite" group of strata (Lower Tertiary) proves that "extensive tracts of country in the regions of the Rocky Mountains, and east of them in Nebraska and other north-western territories, were occupied by bays, inlets, estuaries, &c., of brackish water. The shores of these ancient estuaries, &c., supported dense forests of large trees, and a growth of other vegetation far exceeding in luxuriance anything now met with in these latitudes. The presence of true fan palms of large size, the remains of crocodiles, as well as the affinities of the mollusca found in these beds to southern forms, all point to the existence of a tropical rather than a temperate climate during their deposition."*

The Equatorial waters, constantly propelled by the influence of the Trade Winds through such an extensive land-locked bay, inducing upon its shores a tropical vegetation, would by the warmth infused into the air so modify the climate farther north that the winter, rainy, cloudy, and foggy, would probably in no part of North America have had a temperature differing much from that of Britain at the present time.

* "United States Geological and Geographical Survey of Colorado, &c.," 1874, pp. 22, 23.

The general idea that in high northern latitudes the country must be a desert waste, either covered by ice or snow, or by an exceedingly scanty moss vegetation, being so contrary to the startling fact, as described by Professor Nordenskjold, the re-consideration of the fossil flora of the Polar Regions may become a necessity; whether it may so far agree with that of the forests of Western Siberia that the plants of which it consists may have lived if placed under similar circumstances, and whether the geological position of all or any of these plant-beds would coincide with such a supposition as co-ordinates them with that of the Glacial Period farther south. The accounts of the fossil and sub-fossil plants of the Parry Islands may probably favour the idea of a Siberian climate, whilst those of Disco, &c., may be incompatible.

The subsidence which, allowing the influx of Equatorial waters, produced a tropical climate in the central parts of North America, if it progressed farther south, and caused submergence to any considerable depth of the low ridge of land which forms the Isthmus of Panama, would permit the Equatorial waters to be propelled by the Trade Winds directly into the Pacific Ocean; and thus, in accordance with the extent of the immersion, the climate of the Northern Hemisphere would be entirely altered. Probably the accession of the Equatorial water of the Atlantic to that of the Pacific would so much increase the moisture of the atmosphere that, amongst other changes, the Himalayas would be covered with a greater fall of snow, and its Glaciers extend to a much lower level, especially on their southern aspect. The warm Equatorial waters would cease to circulate in the bay which once stretched into the interior of the North American Continent. The power which causes the Gulf Stream being

diverted, this great ocean current would no longer exist; and that immense portion of the Equatorial water for which there is not sufficient area in the Straits of Florida to form part of its volume, and as an overflow mixes with the North Atlantic, would also be diverted in the same way. A diminution of temperature would follow sufficient to change the winter rainfall of Britain and Western Europe into a fall of snow; at the same time sufficient warmth would remain in the ocean to generate the vapour from which the snow would be derived, not in quantities such as many imagine occurred during the Glacial Period, but plenty to fill the valleys entirely with their respective Glaciers. This I have illustrated in the case of a minor valley, tributary to the Mersey, not because I do not think that the principle is of general application, but because I have there had special opportunity of examining the phenomena which have resulted from its action.

The observations on Central America have been too few to determine, from geological evidence, the former existence of such a depression as I have supposed, yet there is good ground for supposing that such has taken place.* All around the Bay of Mexico and on the western coast of Central America there has been a former subsidence of the land to a considerable extent below its

* In reference to recent investigations of the fauna of Lake Nicaragua, by Drs. Gill and Bransford, it has been considered that "the element of especial interest is the association of characteristically marine forms, such as a species of Megalops, a shark and a saw-fish, with fresh-water types. The most probable cause of such a combination is the detention and survival of salt-water fishes in inlets of the sea that have become isolated and gradually transformed into fresh-water lakes." *Nature*, Oct. 11th, 1877; page 505.

present level. Many Mollusks* and Echinoderms† are found in the two oceans which are either identical or very similar in species. The altered conditions in the Pacific, upon a re-elevation of the land, must have been the destruction of a very large number of species; but the number in which this similarity exists is sufficient to lead the late Mr. P. P. Carpenter, Mr. Alexander Agassiz,‡ and Professor Wyville Thomson to consider that they may be indicative of a former intercommunication between the two seas.

FEBRUARY 13TH, 1877.

THE PRESIDENT, HUGH F. HALL, F.G.S.,
in the Chair.

The following communication was read:—

ON SOME OF THE INFUSORIAL EARTHS, AND THE USES TO WHICH THEY ARE APPLIED.

BY ALFRED MORGAN.

THE student of Lyell's "Elements of Geology" has his interest awakened at an early stage of his enquiries by the narrative there given of the discoveries of Professor Ehrenberg, of Berlin, as to the organic origin of a silicious stone called Tripoli, a substance which has long been well known in the useful arts, being used in a pulverised form for polishing stones and metals.

* "The Mollusca of the West Coast of North America," by Philip P. Carpenter.—Report of the British Association, 1856, p. 363.

† "The Depths of the Sea," by Professor C. Wyville Thomson, F.R.S., &c., p. 13.

‡ Quoted in "Depths of the Sea," p. 14.

Ehrenberg found that this deposit is composed of the remains of countless millions of microscopic Infusoria, such as abound in fresh water lakes and ponds, and which naturalists now concur in regarding as vegetable organisms, and describe by the terms Diatomaceæ and Desmidæ.

At Bilin, in Bohemia, there is a single stratum of wide area no less than 14 feet in thickness; and under microscopic examination the entire mass is found to consist of the silicious plates of Diatomaceæ, united together without any visible cement. "It is difficult to convey an idea of their extreme minuteness; but Ehrenberg estimates that in the Bilin Tripoli there are 41,000 millions of individuals of the *Gaillonella distans* in every cubic inch, which weighs about 220 grains, or about 187 millions in a single grain. At every stroke, therefore, that we make with this polishing powder, several millions, perhaps tens of millions, of perfect fossils are crushed to atoms." *

The observations of Ehrenberg led to the discovery of similar deposits in many other localities, and we now know that such beds are in process of formation over extended areas. The indestructible shells of the minute organisms occurring so abundantly in the tripoli are found in immense numbers beneath peat bogs, where they constitute strata often many feet in thickness and of great extent. The cake or "pan" of bog iron ore found in such positions consists of the slender articulated threads or plates, partly silicious and partly ferruginous of *Gaillonella ferruginea*. The source of the iron which imparts the jet black colour to the oak embedded in the peat was not known until Ehrenberg demonstrated its

* Lyell's "Elements," 6th Edition, p. 25.

vegetable origin.* Bog iron ore is largely used in gas manufacture in the purifying process, and when supersaturated with the impurities of which it deprives the newly-made gas, it becomes deodorised and pure on exposure to the atmosphere. Other minute organisms, whose skeletons constitute the mass of the deposits which may be grouped under the term infusorial, inhabit the ocean in inconceivable multitudes, and, while living, produce the beautiful phenomenon of luminosity of the waters. In the harbour of Wismar alone, Ehrenberg calculated that an annual deposit of 18,000 cubic feet was laid down. The countless numbers, rapid multiplication, and wide distribution of these microscopic organisms, place them among the most powerful agents that operate in the production of physical changes. The mind is filled with astonishment in the contemplation of the aggregate results of the life history of such minute forms. Ehrenberg's two great works are his "Mikrogeologie" and "Die Infusionsthierchen als Vollkommene Organismen," in which the geographical distribution and natural history of the group is elaborately worked out.

The "Challenger" explorations of deep sea areas, not to refer to other investigations, have shown that the impalpable mud or ooze of the Atlantic is made up almost entirely of such minute organic bodies as these. Some of the shells or skeletons are calcareous, and appear to be identical with the organisms which abound in the chalk of Europe, while others are silicious. One of the Atlantic deposits has been traced over a distance of 1,300 miles in length by 600 miles in breadth. We have here all the conditions in operation for the produc-

* Lyell's "Principles," 10th Edition, vol. ii, 501.

tion of a vast chalk deposit, and additional evidence in support of uniformitation theories in geology.

In tropical seas the great agents in the extraction of carbonate of lime from the ocean are the corals; but in extra tropical regions this result is accomplished chiefly by the Rhizopoda. Rivers discharge into the ocean carbonate of lime, &c., in solution, and the Testacea perform the same function, but to a less extent, as do the Foraminifera, in separating the lime again in a solid form. The only means by which a limestone rock could, at this period of our earth's history be formed, is, so far as we can tell, by the agency of organic life. Bischof has estimated that the water of the sea contains five times the amount of carbonic acid which would be necessary to hold in solution the total quantity of carbonate of lime that it holds; and, if so, before any could be precipitated, the amount of carbonate of lime would have to be increased five fold. The segreation of the carbonate of lime is now accomplished by corals and Rhizopoda for the most part.

In peat bogs, swamps, &c., there are often found layers of a white silicious paste, composed of the remains of minute organisms which, when dry, present the appearance of a friable chalk, and which, under microscopic examination, proves to be an aggregation of diatomaceæ, many hundreds of which have been described by Ehrenberg and Bailey. Infusorial deposits may, therefore, be either of marine or of fresh water origin.

Bischof mentions a diatomaceous clay amongst the deposits lying under Amsterdam, at a depth of 138 feet from the surface. It is eight feet in thickness, and contains silicious remains to the extent of about one-half of its entire mass.

The Calcaire Grossier of the Paris Basin contains the remains of foraminifera in countless millions; and we may see in the buildings of Paris, where it has been extensively used, a monument of their existence.

The deposit at Bilin is not the only one of large extent that has been investigated. There are beds of scarcely inferior dimensions of a similar nature at Berlin and at Planitz (Saxony). It also occurs at Lüneberg, in a stratum of 28 feet in thickness, and at Kliecken, near Dessau, and in the vicinity of Cassel.

In England a stratum of considerable magnitude has been found in Surrey, at the base of the chalk hills, and elsewhere. In Ireland there is a celebrated stratum on the banks of the River Bann, County Down, and which, from its being much in request for polishing purposes, is locally known as Lord Roden's plate powder.

A similar earth is found in Lapland, in the Isle of France; at San Fiora, in Tuscany; and in Africa, Asia, and New Zealand. In America it has been found in a great number of localities, and occasionally in enormous quantities. Perhaps the most remarkable deposit in the United States is that upon which the city of Richmond, Va., is built; this deposit is in places more than 20 feet in thickness, and has been traced by Professor W. B. Rogers, who was the first to make known its nature, from Herring's Bay, on the Chesapeke, Md., to Petersburg, Va. Professor George H. Cook, State Geologist of New Jersey, in his papers for 1874, reports on an interesting deposit at Drakeville, N.J. He says:—"It has been known as a white earth, or marl, for a long time, and some years since was dug out and spread upon the soil as a manure; it has also been observed to possess remarkable excellence for scouring silver. The establishment of a manufactory for making nitro-glycerine and giant powder at M'Cains-

ville, in which infusorial earth imported from Germany was used, led to an examination of the deposit, when it was found to be the same material with that they were bringing from Europe."* Professor Cook describes the deposit as occurring in a depression of the surface at the foot of Schooley's Mountain, and covered by a swamp of black earth about a foot thick. A trial pit sunk in the middle of the swale indicated 12 inches of black earth, 8 inches of very light infusorial earth, and 12 inches more of denser infusorial earth. Professor Cook continues:—"There is little doubt that other deposits will be found in this gneissic region, . . . and it can easily be distinguished from any other white earth by its not effervescing with acids, as white marl does; by its not becoming plastic when wet, as white clay does; and by its dissolving almost entirely in a strong solution of boiling water and washing soda."

On the Uses to which Infusorial Earth is Applied.

As an Article of Food.—Strange as it may appear to us, the Laps are said to mix this earth with the bark of trees, as an occasional "famine-fare," when better provisions fail. A deposit occurring at Lillhaggsjon (Sweden) has long been described as "edible," and it is said the Indians dwelling along the banks of the Amazon are accustomed to eat certain white earths found there.

In the Manufacture of Dynamite.—Infusorial earths are of considerable importance in this manufacture. According to Professor Cook, the industry is valued at £600,000 per annum, and some dynamites require as much as 25 per cent. of infusorial earth in their production. Professor Cook gives 47·12 per cent. of soluble

* See a paper by Dr. Wall, *Quarterly Journal of Science*, vol. vi, N.S. London, 1877.

silica as the result of his analysis. As an absorbent and carrier of liquids, the infusorial earth has been found to be the substance most adapted for use. It takes up three to five times its weight of water, oil, &c., and is extensively used with disinfectants.

In order to bring nitro-glycerine within the range of articles of transport, Nobel devised the substance known as dynamite, in which the explosive oil is simply carried by the inert, pulverulent silicious earth. After careful preparation, which consists in the thorough removal of all organic matter by heat, &c., the earth is rolled and pressed and sifted when it is ready for use. Fifty pounds of the earth is put into a flat wooden tank and covered with 150lbs. of nytro-glycerine, which is then thoroughly mixed with it. After half an hour has elapsed it is ready for removal to the cartridge moulds, in which parchment paper is used.*

In Agriculture.—As silica enters largely into the composition of the stalks and outer coverings of cereals, the use of infusorial earth as a fertiliser for lands deficient in silica has been suggested; and Professor P. B. Wilson has shown that the very minute skeletons or shells of which infusorial earths are composed are *carried up as such* into the body of the plant during the process of growth. Professor Wilson made many examinations of wheat grown under such conditions, and was led to expect that the undissolved diatomaceous forms that occur in the earth, used as a fertiliser, would be found in the tissues of the plant. With this idea he subjected several growths of wheat to a careful microscopic examination, and thus expresses the result of his investigations: —"My labours have been amply rewarded by one of the

* Dr. Wahl: op. cit.

most enchanting views that has ever fallen to my lot to behold through twenty years of varied scientific investigations. When the epidermal siliceous coating was adjusted upon the field of the microscope, some 36 forms of the diatomaceæ were observed." Professor Wilson failed to find a single diatom in wheat straw not so grown. He thus concludes his report:—"I look upon this application of vegetable silica to fertilising purposes as the most important adaptation of matter for the reproduction of vegetation that has ever been discovered." Its *miscellaneous applications* include the employment of the earth as a polishing agent. For this purpose its hardness and wonderfully fine state of division fit it admirably. Under the name of "Electro-Silicon," &c., the Nevada earths are extensively sold in the United States; and, as the Tripoli of commerce, its wide reputation in Europe attests its excellence for the purpose.

Being a very poor conductor of heat, it forms a suitable covering for ice, beer cellars, fire-proof safes, steam boilers, powder magazines, refrigerators, &c. Its superiority over the substances generally used would seem to be placed beyond doubt. "It is extremely light, being nearly five times as light as dry earth, and only about half the weight of dry coal ashes; it is not combustible, remaining unaffected by the hottest fire."

Floating bricks may be made of infusorial earth, clay being added to assist in binding it firmly together. Such bricks were said to have been made by Vitruvius, Pollio, and Pliny. In 1791 they were again produced by Giovanni Fabroni in Tuscany. Fabroni's bricks were equal in strength to those made from ordinary clay, were infusible, and, being very poor conductors of heat, might be held by one end while the other was red hot. Fabroni, as an experiment, constructed the powder

magazine of a wooden ship of these bricks; the vessel being set on fire, sank, without exploding the powder. In 1832, Count De Nantes and Fourriet employed such bricks in the construction of powder magazines, &c., on board ships.

In the preparation of cement and of artificial stone, infusorial earth is largely used. In the "Ransome stone" or apoenite, which is composed of sand and silicate of soda thoroughly mixed and moulded into blocks, which are saturated with a solution of chloride of calcium, the result is the formation of an insoluble silicate of lime, which firmly cements the particles of the stone together, and of chloride of sodium. This latter has to be removed by the free application of water to prevent efflorescence and secure the durability of the stone. This washing process was found to be so tedious and expensive in its thorough application that Mr. Ransome devised, after many experiments, the following process, in which the use of chloride of calcium is avoided.

Suitable quantities of lime (or substances containing lime) and soluble silica (*i.e.*, infusorial earth) are mixed with sand and a solution of silicate of soda or potassa, which, when intimately incorporated, are moulded, and allowed to harden gradually. As rapidly as the soda or potash is set free, it dissolves some of the infusorial silica, and again gives it up to the lime, forming more cement, and thus acting as the carrier of the silica to the lime until eventually all is combined, and, as the result of chemical changes, the whole of the alkali is fixed, leaving nothing to be washed out. The mass gradually becomes thoroughly indurated, and is converted into a compact stone capable of withstanding enormous pressure, and increasing in strength and hardness *with age.*

In pottery, infusorial earth has received several important applications. When fused, for example, with borate of lime, an excellent glazing is produced, which is useful not only for pottery of all kinds, but for enamelling iron and other metals.

The enumeration of all the uses to which this earth is applied would lead us over a very wide field. It has been of service in the manufacture of sealing-wax, soap, paper, ultramarine, &c. And, no doubt, as it becomes more widely known, the extent of its applicability will be comensurably increased.

In addition to the paper by Dr. Wahl, to which reference has been made, I have had before me one by Dr. Birkenhead, on "Micro-geology," which is contained in Vol. XV. of the "Transactions of the Historic Society of Lancashire and Cheshire," and which is of great interest.

MARCH 13TH, 1877.

THE PRESIDENT, HUGH F. HALL, F.G.S.,
in the Chair.

The following communications were read:—

COPPER PITCH-BLENDE AND ITS ASSOCIATIONS.

BY W. SEMMONS.

THIS mineral, formerly of such rare occurence as to be unnoticed in almost every work on Mineralogy, has been lately imported into Liverpool in considerable quantities.

Dana in his edition gives the analyses of some varieties of this ore; but its very existence was almost forgotten, and a writer well known among Mineralogists only twelve months since included it in his list of doubtful minerals.

Its physical characters are :—

Colour—Brown, almost black; lustre pitch-like.

Streak—Same as colour.

Hardness—6.

No crystal has yet been found.

This high degree of hardness is remarkable, as it far exceeds that of any other ore of copper. It is found associated with Chrysocolla in the great mining district of North-west Mexico. It occurs in nodules of various sizes, also in veins, varying from $\frac{1}{8}$ to $1\frac{1}{2}$ inch in width, and covered on all sides by different varieties of the Chrysocolla. Its composition appears to vary, also its fusibility. In some cases it is quite infusible, at others it melts with ease before the blow-pipe. The most fusible varieties seem to contain a large percentage of manganese.

The following analyses, by Mr. W. M. Hutchings, of Copper Pitch-Blende and the associated Chrysocolla show their marked distinctness and individuality :—

	Chrysocolla.	Copper Pitch-Blende.
Silica	66·25	27·98
Oxide of Copper	25·69	28·59
,, Lead	·12	·41
,, Iron	·26	10·94
,, Zinc	·34	1·54
Lime	·74	·92
Magnesia	1·06	—
Water	6·13	8·30
Alumina	—	·15
Oxide of Manganese	—	17·53
,, Cobalt	—	·35
Oxygen	—	3·60

From the above it seems this ore differs from Chrysocolla in containing much less silica and much more iron;

while manganese, which is absent from the Chrysocolla, is found in considerable quantities in Copper Pitch-Blende.

In order to pass any opinion on the formation of this ore, it is necessary to look at the Chrysocolla and other minerals associated with it. They are:—

Silica, in the form of quartz and of calcedony, as also jasper, is found freely disseminated through the whole, and often incrusting the mammillated Chrysocolla.

Gypsum occurs in veins from a line to three inches thick. Calcite is also found in small quantities.

Pyrolusite in thin botryoidal incrustations occurs on the Copper Pitch-Blende. This is easily separated from the parent mass, and seems to be a seggregation from it.

Looking at the tendency in compounds of manganese to assume dendritic and other forms, and to separate themselves from the minerals by which they are surrounded, I am inclined to consider these nodules—which, occurring so frequently, have amounted to hundreds of tons in the past few months' importations at this port—are secondary products. By this I mean a deposit not existing in its present form in the original mass. The manganese molecules have separated themselves from the parent mass, together with the iron molecules, and have thus set up a new combination, much poorer in silica than the surrounding Chrysocolla.

The Chrysocolla associated with the Copper Pitch-Blende is so remarkable in many respects, that I reserve its description for a future paper.

THE GLACIAL STRIÆ OF THE COUNTRY AROUND LIVERPOOL.

By George H. Morton, F.G.S.

In this communication I propose to give a general description of the Glacial Striæ which are of such frequent occurrence on the surface of the sandstone rocks in the country around Liverpool.

This is the only area in England so far south, and so far away from a hilly or mountainous district, where the rocks have been found to be striated, except, perhaps, the coast of Durham, where similar striæ occur on limestone near the coast. In Leicestershire, at Mount Sorrel, in 1867, I saw the Syenite striated, probably by ice. The occurrence of such indications of moving ice in North Wales, the north of England, and in Scotland is more easily accounted for, on account of the proximity of hills or mountains from which glacial ice may have radiated.

In 1859 * I described for the first time, evidences of the action of ice on the surface of the sandstone in this neighbourhood. Having at that time only found such indications in a single locality, I attributed the striated surface to the grounding of an iceberg in the Glacial sea.

In 1866, † having discovered several additional examples of glaciation on both sides of the Mersey, though at no great distance from it, I began to entertain

* "Traces of Icebergs near Liverpool."—Proceedings, Literary and Philosophical Society, 1859-60.

† "On the Presence of Glacial Ice in the Valley of the Mersey during the Post-Pliocene Period."—Proceedings, Liverpool Geological Society, 1866-7.

the opinion that a Glacier, or at least a field of moving ice, had descended the valley of the Mersey during the early part of the Glacial period.

By 1870 * I had discovered similar evidences of ice-action at greater elevations, several miles from the river, and was consequently compelled to adopt another theory, viz.: that a great ice-sheet had passed over this part of the country from the S.E. to the N.W. This direction seemed the most probable from the general contour of the ground; and was supported by an examination of the quartz pebbles protruding from the striated surfaces being rubbed or broken on the side from which the ice was supposed to have travelled.

The following are the descriptions of the striated surfaces, in the order in which they were discovered.

PARK HILL ROAD.

The first striated surface discovered was between Park Hill Road † and the Dingle. It has since been covered by the erection of cottages over it. The surface of the rock was 120 feet above the Ordnance datum, and the strata belonged to the Pebble-beds of the Bunter formation. The direction of the striæ was N. 42° W., of course allowing 22½° W. for magnetic variation. In this instance, as in all the other areas, the rock had been originally covered with Boulder-clay; otherwise the striæ would have been obliterated. The clay had been removed for brick-making, and when the surface of the rock had been washed by rain the grooves and striæ became visible. A slab of sandstone was taken from the

* "On the Glaciated condition of the surface of the Triassic Sandstone around Liverpool."—Report, British Association, 1870.

† "On Glacial Surface Markings near Liverpool.—*Quarterly Journal Geological Society*, 1862.

surface and deposited in the Liverpool Free Museum. It shows the character of the striæ, which present a remarkably uniform appearance when seen extending over a considerable area. Such sandstone does not take a polish, like the glaciated greenstone and slaty rock of North Wales; but it assumes a flat surface and exhibits numerous striæ and long grooves which frequently extend several yards in perfectly straight lines—parallel with each other. Ice would not striate the rock over which it passes in this manner, unless it enclosed stones and boulders embedded in the bottom of it.

BOUNDARY STREET, KIRKDALE.

The second locality was situated in a brickfield, about 50 yards north of Boundary Street, and 150 yards west of Heriot Street (formerly Gore Street), where an area of about ten square yards of striated rock was exposed for several years, but is now covered with houses.* The surface was about 80 feet above the Ordnance datum, and the sandstone belonged to the Keuper formation. The direction of the striæ was N. 15° W.

STANLEY ROAD, KIRKDALE.

The third locality was also discovered in brickfields on the west side of Stanley Road, opposite the Stanley Hospital, more recently erected, and about 600 yards from the locality last described, with which it may have possibly communicated.* The rock surface was about 80 feet above the Ordnance datum, and the direction of the striæ N. 15° W.

FLAYBRICK HILL, CHESHIRE.

The fourth locality was at Flaybrick, and is a locality of considerable interest, for striæ have been

* *Ibid.*—*Quar. Jour. Geol. Society*, 1862.

found both on the sides and base of the hill. The form of Flaybrick Hill was formerly very remarkable, and it attracted attention many years ago, for it had a very steep escarpment facing the east or north-east,* which is unusual in this neighbourhood, but it has now been almost entirely removed for building purposes. It is an outlier of the Bidston range of hills, and seems to have been worn into its precipitous shape by the passage of ice rather than by the action of water. The strata belong to the Keuper formation, which rests on the Bunter Sandstone near the base of the hill. The striæ were first observed at an elevation of one hundred and twenty feet above the Ordnance datum, half a mile S.E. of the Telegraph Station on Bidston Hill, and again at seventy feet, the direction being N. 32° W., and N. 30° W.† They were soon after observed on the western side of the hill one hundred feet above the same datum-line, where the direction was N. 20° W. Mr. D. Mackintosh, F.G.S., has recently described striæ W. 30° S. on Flaybrick Hill, just half-a-mile due south from St. James's Church. The striæ are nearly effaced, but the rock seems to have presented a glaciated surface, which was too thinly covered with drift to have been preserved.

NORTH HILL STREET, NORTH OF ST. SILAS'S CHURCH.

The next striated surface was found in 1863, in the fields on both sides of North Hill Street, and it presented two of the largest areas discovered, each fully five hundred square yards, but they are now almost entirely covered with rubbish.‡ The surface of the rock is one

* Proc. Literary and Philosophical Society, 1844-5, p. 97.

† *Ibid.*—*Quar. Jour. Geol. Society*, 1862.

‡ *Ibid.*—Rept. Brit. Assoc., 1870.

hundred and sixty feet above the Ordnance datum, and the strata belong to the Pebble-beds of the Bunter formation. The direction of the striæ is N. 35° W. On the rock surface on the north of North Hill Street I noticed an oblique grove, crossing the regular striæ at an angle of 35°, that was N. 70° W., and a specimen was obtained showing this exceptional grove and deposited in the Museum of the Royal Institution.

WAVERTREE.

Near the village of Wavertree, in Victoria Park,* I found the rock to be striated, but an excavation for building destroyed the surface, which was 170 feet above the Ordnance datum. The rock belongs to the Pebble-beds of the Bunter formation, and the direction of the striæ was N. 32° W. Specimens were obtained and placed in the Liverpool Free Museum.

THATTO HEATH.

A fine striated surface occurs along the top of the rock on each side of the railway-cutting a little west of Thatto Heath. It is on the south-west slope of the hill, about 290 feet above the Ordnance datum, and the strata belong to the Pebble-beds of the Bunter. This area is of especial interest on account of its distance being nine miles from Liverpool, and was discovered by Dr. Ricketts, F.G.S., in 1870.† The direction of the striæ is W. 40° N.

OXTON, CHESHIRE.

At Oxton, about half-a-mile S.E. of Christ Church, there is a small area of striated sandstone, at an elevation of 100 feet, on the Keuper formation. The direction

* *Ibid.*—Rept. Brit. Assoc., 1870.

† "The Sections of Strata exposed on the Huyton and St. Helens Branch Railway."—Proc. L'pool Geol. Society, 1869-70.

of the striæ is N. 24° W. Mr. Robert Bostock discovered the locality. Close to the spot the surface of the yellow-beds of the Upper Bunter Sandstone present a very remarkable flat surface beneath the Boulder-clay, probably caused by the planing action of ice on strata too soft to be permanently striated. Recently Dr. Ricketts described two additional areas in the locality, one close to the Mission House, on the Happy Valley Road, N. 40 W., and another between Carlton Street and Glover Street, Happy Valley Road, and Woodchurch Road, N. 22½° W. The elevations being respectively 62 feet and 105 feet above Ordnance datum.

PARK ROAD.

In 1870 I found loose blocks of striated sandstone on the broken surface of the Keuper formation east of Park Road—opposite Northumberland Street—indicating a striated area close to the place.

MILLER'S BRIDGE.

Another striated area has recently been discovered to the east side of Regent's Road, near the toll-gate at Miller's Bridge, by Mr. T. Mellard Reade, C.E., F.G.S.,* about 90 feet above the Ordnance datum. The strata belong to the Keuper formation, and the direction of the striæ is N. 28° W. On this surface there are several cross grooves at a considerable angle to the regular striæ.

CROSBY.

At the village, in a field south-west of the Police Station, Mr. Reade found another striated surface.† It is only 25 feet above the Ordnance datum. The rock is

* "Glacial Striæ at Miller's Bridge, near Liverpool."—Proc. L'pool Geol. Society, 1872-3.

† Proc. L'pool Geol. Society, 1873-4, p. 72.

the Keuper Sandstone, and the direction of the striæ N. 40° W. In the adjoining quarry there is a fine section showing the perfectly flat glaciated surface, with the super-imposed Boulder-clay. A large decomposed greenstone boulder rests on the sandstone.

LITTLE CROSBY.

Last year, 1876, another striated area was discovered by Mr. Reade,* in a yard attached to a farmhouse close to the large quarry at Little Crosby. The surface of the rock, Keuper Sandstone, is about 35 feet above Ordnance datum, and the direction of the striæ N 22° W.

The parallelism of the striæ in each of these glaciated areas is remarkable. Although particular grooves occasionally run into each other, it may be explained by stones at the bottom of the ice having gradually altered their position.

Several instances have been noticed where oblique grooves intersect the principal striæ at a considerable angle, as at North Hill Street and at Miller's Bridge. I do not regard these exceptional striæ as of any importance, for they appear to have been formed after the surface had been striated in a uniform direction, and seem to have been caused by the final breaking up of the ice.

There are large areas around Liverpool where the rock is exposed with a denuded surface, and consequently where no indication of the passage of ice has been preserved. It is only in situations where the Boulder-clay has been deposited on the rock, that the striated surfaces

* "Glacial Striations at Little Crosby."—Proc. L'pool Geol. Society, 1876-7.

have been found, and only in exceptional places then. In the low-lying land, where the soft sandstones of the Bunter occur, no trace of moving ice has been observed --excepting the flat surfaces already described.

Since the foregoing descriptions of striated areas were written, Mr. A. Strahan, F.G.S., of the Geological Survey, has kindly given me a list of several additional localities where he has observed glaciated surfaces in this neighbourhood; and Mr. C. E. De Rance, F.G.S., has allowed me to see a proof sheet of the "Memoirs of the Superficial Deposits of the South-west of Lancashire." These important additions to the areas previously known have enabled me to compile the following list of glacial surfaces in the country around Liverpool; but I have added a number of localities from a paper "On the Evidences for the Ice-sheet in North Lancashire and adjacent parts of Yorkshire and Westmoreland," by Mr. R. H. Tiddeman, M.A., F.G.S., which continue the connection of this district with the country about Preston and Lancaster. It seems unfortunate that there is no recorded instance of glacial striæ on the south-eastern side of Wirral, or near Chester, for the discovery of such an area would connect this district with North Wales, glacial striæ having been recorded in the neighbourhood of Holywell.*

* Discovered by Mr. G. Shrubsole, F.G.S. "Records of Glacial Striæ in Denbighshire, Flintshire, and Anglesea," by G. H. Morton, F.G.S.—Proc. L'pool Geol. Society, 1875-6.

LOCALITIES OF GLACIAL STRIÆ IN SOUTH-WEST LANCASHIRE AND CHESHIRE,

ARRANGED ACCORDING TO DISTANCE FROM LIVERPOOL EXCHANGE.

NO.	LOCALITY.	DIRECTION.	DISCOVERER.	WHERE DESCRIBED.
1	Park Road, Liverpool	Loose Blocks only.	G. H. Morton, F.G.S.	Not previously described.
2	North Hill Street, Liverpool	N. 35° W.	Do.	*Rept. Brit. Assoc.*, 1870.
3	Boundary Street, ,, ...	N. 15° W.	Do.	*Quar. Jour. Geol. Soc.*, 1862.
4	Stanley Road, ,, ...	N. 15° W.	Do.	Do.
5	Park Hill Road, ,, ...	N. 42° W.	Do.	Do.
6	Miller's Bridge, Bootle	N. 28° W.	T. M. Reade, F.G.S.	*Proc. L'pool Geol. Soc.*, 1872-3.
7	Christ's Church, Oxton	N. 24° W.	R. Bostock.	*Rept. Brit. Assoc.*, 1870.
,,	,, ,, ,, ...	N. 22½° W.	Dr. Ricketts, F.G.S.	*Proc. L'pool Geol. Soc.*, 1876-7.
,,	,, ,, ,, ...	N. 40° W.	Do.	Do.
8	Flaybrick Hill, Birkenhead	N. 30° W.	G. H. Morton, F.G.S.	*Quar. Jour. Geol. Soc.*, 1862.
,,	,, ,, ,, ...	N. 32° W.	Do.	Not previously described.
,,	,, ,, ,, ...	N. 20° W.	Do.	Do.
,,	,, ,, ,, ...	N. 10° W. N. 22° W.	E. Hull, F.G.S.	*Trans. M'chester Geol. Soc.*, 1864.
,,	,, ,, ,, ...	W. 30° S.	D. Mackintosh, F.G.S.	*Quar. Jour. Geol. Soc.*, 1877.
9	Wavertree	N. 32° W.	G. H. Morton, F.G.S.	*Rept. Brit. Assoc.*, 1870.
10	Crosby	N. 40° W.	T. M. Reade, F.G.S.	*Proc. L'pool Geol. Soc.*, 1873-4.
11	Little Crosby	N. 22° W.	Do.	Do., 1876-7.

NO.	LOCALITY.	DIRECTION.	DISCOVERER.	WHERE DESCRIBED.
12	Thatto Heath	W. 40° N.	Dr. Ricketts, F.G.S.	*Proc. L'pool Geol. Soc.*, 1869-70.
13	Pool Hall Rocks	N. 43° W.	A. Strahan, F.G.S.	Not previously described.
14	Farnworth Church Yard.....	W. 8° N.	Do.	*Mem. S.W. of Lancashire, Geol. Survey*, 1876.
15	Appleton, near Church	W. 8° N.	Do.	Do.
16	Runcorn—Bed of Mersey	W. 8° W.	Do.	Do.
17	Runcorn—Bridgewater Company's Quarry.	?	Do.	Not previously described.
18	Middlehurst's Delf, St. Helens	W. 33° N.	Do.	*Mem. S.W. of Lancashire, Geol. Survey*,
19	Crank, St. Helens.....	W. 30° N.	Do.	Not previously described.
20	Garswood, St. Helens	W. 30° N.	Do.	*Mem. S.W. of Lancashire, Geol. Survey*,
21	Horwich Colliery	W. 12° N.	E. Hull, F.G.S.	Do.
22	Grey Heights, Chorley	N. 22° W.	R. H. Tiddeman, F.G.S.	*Quar. Jour. Geol. Soc.*, 1872.
23	Euxton, Preston	N. 22° W.	Do.	Do.
24	Ordsall, Manchester.....	N. 40° W.	J. Plant, F.G.S.	*Trans. Man. Geol. Soc.*, 1868.
25	Mellor Beacon, Blackburn	W. 10° S. W. 13° S.	J. Eccles. R. H. Tiddeman, F.G.S.	*Quar. Jour. Geol. Soc.*, 1872.
26	Heysham	N. N. 10° E. N. 40° E.	Do.	Do.
27	Inglebrough Hill	N. 10° E. N. 35° E. N. 22° E.	Do.	Do.

During the last few years several important communications have been brought before the Geological Society of London, descriptive of similar phenomena in districts north of Liverpool, in which attempts have been made to show that during the Glacial period a great ice-sheet from Norway and Scotland advanced over the north of England. Mr. D. Mackintosh, F.G.S., contributed a paper "On the Traces of a Great Ice-sheet in the Southern part of the Lake-district and in North Wales;" this with Mr. Tiddeman's paper, previously referred to, afford evidence that the theory of this great ice-sheet has been very generally accepted. Mr. Tiddeman's subject is intimately connected with this district, for he describes glacial striæ at Chorley, running N.N.W., only 15 miles from Thatto Heath—one of the glaciated areas I have described. He is of opinion that the great ice-sheet he describes advanced over this district, and that the direction was S.S.E., instead of N.N.W., as I supposed it to be in my paper read before the British Association in 1870.

Geologists are beginning to think that the ice-cap theory has been pushed too far; and with regard to this part of England, it seems to be a question whether a great thickness of glacial ice moving over the country would not have produced a more uniform direction of the striæ in the numerous areas recorded. It seems probable that the drifting and frequent grounding of field-ice in a shallow sea would be more likely to produce the striated surfaces that have been described, and at the same time account for the varying direction, which extends over 65° in the immediate neighbourhood of Liverpool, without regarding the area discovered by Mr. Mackintosh, where the surface has been weathered. If that

the variation would amount to no less than 112.° The passage of field-ice carried along by tidal currents in the same general direction, and occasionally grounding on the sandstone bottom, would be very likely to cause striæ with the amount of variation I have shown the respective areas to possess; whereas a rigid mass of ice would have probably striated the rocks in a more uniform direction —within a fewer number of degrees than we find to be recorded.

Whichever of these two theories is finally adopted, it seems to me that the striæ were produced before much if any of the Boulder-clay was deposited, and that there is little if any connection between the striated surfaces and the superincumbent clay.

If the ice-cap theory is adopted, it must be admitted that the sandstone surface was partially denuded, after the rock had been striated, otherwise the striæ would have been more generally present; and where the Boulder-clay covers the denuded surface, which it usually does, it is obvious that the denudation must have occurred before the clay was deposited. If, on the other hand, the field-ice theory is supported, it seems unnecessary to suppose any such denudation after the striation of the rock, but that we find the striated surfaces just where ice happened to ground, that the grounding of the ice was exceptional, and that the places where it occurred were at various and irregular distances from each other.

It was my intention to have supplemented this communication with a description of the interesting section of Upper Boulder-clay, Middle Sands and Gravels, and Lower Boulder-clay recently exposed at the north of Liverpool,* but as I have arrived at the conclusion

* A full description of the section will be found in the Rept. Brit. Assoc., p. 110, and *Geol. Mag.* for 1876, p. 526.

that the Glacial Striæ in this neighbourhood are altogether of pre-Boulder-clay origin, it is unnecessary to describe such overlying deposits, although they also belong to the Glacial period. However, I may state that in my opinion the Boulder-clay in the country around Liverpool has been deposited in rather deep water, except during the deposition of the Middle Sands and Gravels, which indicate shallow water conditions and a connection with those great deposits of a similar character which are so conspicuous over North Wales.

I have only to add that the Lower Drift Sand of my former papers is the same formation as that more recently described as the Middle Sands and Gravels, and that the section at the north Docks has presented the only example of what I consider to be a Lower Boulder-clay in the country around Liverpool. The Upper Drift Sand is now described by Messrs. De Rance and Reade as the Shirdley Hill Sand.

ON THE GRAPTOLITES FOUND IN THE LOWER LLANDEILO STRATA NEAR THE CHURCH, SHELVE, SHROPSHIRE.

By G. H. Morton, F.G.S.

In my paper on "The Geology and Mineral Veins of the Country around Shelve" there is a description of the Lower Llandeilo series, a section showing the position of Shelve Church on the upper beds of the series, and a list of fossils containing *Bellerophon perturbatus* and *Dictyonema sociale* from beds close to the church that are well known to contain graptolites.

The position of these Church-beds I very carefully worked out, and considered to be at the top of the Lower Llandeilo or Arenig, and that is the position assigned to them in the section of the Geological Survey (No. 34).

The graptolite *Dictyonema sociale* in the list of fossils represented several species, which I was unable to name when my paper was printed in 1869. I have not been able to visit the place since, but during the years I was working in the district I preserved all the specimens that I found, though it was not until Messrs. Hopkinson and Lapworth's paper appeared in the *Journal of the Geological Society* that I was able to name them.

In 1873 Mr. J. Hopkinson, F.G.S., read a paper before this Society on "The Graptolites of the Arenig Rocks of St. David's, South Wales," when he referred to the Shelve Church graptolites. An abstract of this paper is in the Report of the British Association, 1872. Early in 1874 Mr. Hopkinson read another paper before the society "On some Graptolites from the Upper Arenig Rocks of Ramsay Island, St. David's." In this paper he speaks of the graptolites "having been found in the *lower beds* of the Arenig at Shelve." This paper appeared in abstract in the Report of the British Association, 1873.

In a letter to me, dated 13th January, 1873, Mr. Hopkinson remarks that the Shelve Church-beds are lower than those of the White Grit Mine, and in another, dated 23rd September, 1874, he states that he is "convinced from their graptolites that they are low in the Arenig series—that they are at least nearer the Lower than the Upper Arenig Rocks."

Finally, another paper appeared: "Description of the Graptolites of the Arenig and Llandeilo Rocks of St. David's," by John Hopkinson, Esq., F.L.S., F.G.S.,

and Charles Lapworth, Esq., F.G.S. (read December 16, 1874); *Quar. Jour. of the Geological Society*, vol. xxxi., for 1875, p. 631. In this paper the authors refer the Shelve Church graptolite beds to the middle of the Arenig series. There is a list of the graptolites found by the authors at Shelve.

I had found the following before 1869:—

1. *Didymograptus patulus.*
2. *Clematograptus implicatus.*
3. *Dendrograptus flexuosus.*
4. *Callograptus Salteri.*
5. *Ptilograptus acutus.*

The latter *Ptilograptus acutus* is not in Messrs. Hopkinson and Lapworth's list of Shelve Church species, but they have the following, which I did not find:—

6. *Dendrograptus difflusus.*
7. *Callograptus elegans.*

So that according to their list the beds belong to the middle of the Arenig, with one species indicating a lower and one an upper horizon; while my species indicate the middle, with, however, one species indicating a higher horizon altogether. The position of the Church-beds geologically is Upper Arenig, and there seems little in the palæntological evidence to throw doubt on that conclusion.

Besides, Mr. Hopkinson wrote to me on the 18th January, 1876, in answer to a letter containing my list of species as follows:—"*I am much obliged to you for the list you give. It certainly looks like a higher position for the Shelve Church-beds than I had thought.*"

It seems to me that too much importance is attached to the occurrence of particular species in distant localities, and that they will ultimately be found to occupy *different* horizons when followed over an extended area.

THE CARBONIFEROUS LIMESTONE

AND

MILLSTONE GRIT OF LLANGOLLEN.

By GEORGE H. MORTON, F.G.S.

(Continued from Page 205.)

The following List of Fossils contains the names of 76 species, all of which I have collected myself—no others having been admitted. The Upper Grey Limestone is very fossiliferous, 61 species occurring in it, while in the Lower Brown Limestone only 16 species have been found, and of these 4 species are peculiar to it. If the Carboniferous Limestone is simply divided into Upper and Lower Limestone, 37 species are peculiar to the two upper subdivisions, and 14 species peculiar to the two lower subdivisions, 25 being common to both. The species that are peculiar to the upper and lower subdivisions are often quoted from higher and lower horizons in the formation in other districts, so that perhaps all the information to be gleaned from the list is the general absence of particular zones of species in the Carboniferous Limestone. No doubt diligent search would add to the number of species, and modify the results deduced from the list, but the general conclusions would remain unchanged.

LIST OF FOSSILS FOUND IN THE CARBONIFEROUS LIMESTONE OF THE EGLWYSEG RIDGE, LLANGOLLEN.

	Lower Brown Limestone.	Lower White Limestone.	Upper White Limestone.	Upper Grey Limestone.
PISCES.				
1 *Cochliodus oblongus*, Ag.	.	.	.	*
2 *Helodus* sp.	.	.	.	*
3 *Petalodus Hastingsiæ*, Owen	.	.	.	*
CEPHALOPODA.				
4 *Goldfussianum*, Koninck	.	.	.	*
5 ,, sp.	*	.	.	.
6 *Nautilus globatus*, Sow.	*	.	.	*
HETEROPODA.				
7 *Bellerophon cornu-arietes*, Sow.	.	.	.	*
8 ,, *tenuifascia*, Sow.	*	*	.	*
GASTEROPODA.				
9 *Euomphalus Dionysii*, Goldf.	*	*	.	.
10 ,, *pentangulatus*, Sow.	.	*	*	*
11 ,, *rugosus*, Sow.	.	*	.	.
12 *Murchisonia Verneuiliana*, M'Coy	*	*	.	*
13 *Natica tabulata*, Phil.	.	.	.	*
14 *Natica spirata*, Sow.	.	*	.	.
15 ,, sp.	*	.	.	.
16 *Pleurotomaria* sp.	.	.	.	*

	Lower Brown Lime-stone.	Lower White Lime-stone.	Upper White Lime-stone.	Upper Grey Lime-stone.
17 *Pleurotomaria* sp., Sow	.	*	.	.
18 *Stroparollus costellatus*, M'Coy	.	*	.	.
DIMYARIA.				
19 *Cypricardia*, sp.	.	.	.	*
20 *Myacites sulcatus*, Flem.....	.	*	.	*
21 *Pinna flabelliformis*, Mart.....	.	.	.	*
22 *Sanguinolites arcuatus*, Phil.	.	.	.	*
23 ,, *clava*, M'Coy	.	.	.	*
MONOMYARIA.				
24 *Aviculo-pecten micropterus*, M'Coy.....	.	.	.	*
25 ,, ,, *plicatus*, Sow.	.	.	.	*
26 ,, ,, sp.	.	*	.	.
BRACHIOPODA.				
27 *Athyris ambigua*, Sow.....	.	.	.	*
28 ,, *expansa*, Phil.	.	*	.	*
29 ,, *Royssii*, Léveillé	.	*	.	.
30 *Chonetes papilionacea*, Koninck.....	.	*	.	*
31 *Orthis Michelini*, Koninck	.	.	.	*
32 ,, *resupinata*, Mart.....	.	.	.	*
33 *Productus aculeatus*, Mart.....	.	.	.	*
34 ,, *comoides (Llangollensis)* Sow...	*	*	.	.

	Lower Brown Lime-stone.	Lower White Lime-stone.	Upper White Lime-stone.	Upper Grey Lime-stone.
35 *Productus cora*, D'Orb.	*	*	*	*
36 ,, *costatus*, Sow.	.	.	.	*
37 ,, *fimbriatus*, Sow.....	.	.	.	*
38 ,, *giganteus*, Mart.....	.	.	*	*
39 ,, *latissimus*, Sow.....	.	.	.	*
40 ,, *longispinus*, Sow.	.	.	.	*
41 ,, *Margaritaceus*, Phil.	.	.	.	*
42 ,, *Martini*, Sow.	.	.	.	*
43 ,, *punctatus*, Mart.	.	*	.	*
44 ,, *semireticulatus*, Mart.	.	*	.	*
45 ,, *Youngianus*, Dav.	.	.	.	*
46 *Rhynchonella pleurodon*, Phil.	.	.	.	*
47 *Spirifera bisculata*, Sow.	*	*	*	*
48 ,, *crossa*, Koninck	.	.	.	*
49 ,, *glabra*, Mart.	.	.	.	*
50 ,, *lineata*, Mart.	*	*	.	*
51 ,, *striata*, Mart.....	.	.	.	*
52 *Streptorhynchus crinistria*, Phil.....	.	*	.	*
53 *Strophomena analoago*, Phil.	.	.	.	*
54 *Terebratula hastata*, Sow.	.	.	.	*
BRYOZOA.				
55 *Fenestella membranacea*, Phil.	*	.	.	*

	Lower Brown Lime-stone.	Lower White Lime-stone.	Upper White Lime-stone.	Upper Grey Lime-stone.
ECHINODERMATA.				
56 *Archæocidaris Urii*, Flem.	.	.	.	*
57 *Poteriocrinus crassus*, Koninck	.	*	*	*
CRUSTACEA.				
58 *Griffithides longiceps*, Portl.	.	.	.	*
59 *Leperditia suborbiculata*, Münster	*	.	.	.
ZOOPHYTA.				
60 *Alveolites septosa*, Flem.	*	*	.	.
61 *Chætetes tumidus*, Phil.	*	.	.	.
62 *Clisiophyllum turbinatum*, M'Coy	*	*	*	*
63 *Cyathophyllum Murchisoni*, M. Edw.	.	*	.	*
64 ,, *rugium*, Phil.....	.	.	.	*
65 ,, *Stutchburyi*, M. Edw..	.	*	*	.
66 *Lithostrotion basaltiforme*, Phil.	.	.	.	*
67 ,, *irregulare*, M'Coy.....	.	*	*	*
68 ,, *junceum*, Flem.	.	*	.	*
69 ,, *Martini*, M. Edw.....	.	*	*	*
70 ,, *Portlocki*, M. Edw.....	.	*	.	*
71 *Lonsdaleia rugosa*, M'Coy	.	*	.	*

	Lower Brown Lime-stone.	Lower White Lime-stone.	Upper White Lime-stone.	Upper Grey Lime-stone.
72 *Lonsdaleia floriformis*, Flem.....	.	.	.	*
73 *Phillipsastrea radiata*, M. Edw.	.	.	.	*
74 *Syringopora geniculata*, Phil.....	*	*	*	*
75 ,, *ramulosa*, Phil.	.	*	.	.
76 *Zaphrentis cylindrica*, Scouler	.	*	*	*
FORAMINIFERA. (Of undetermined species)*				

The fossils found in the Carboniferous Limestone of the Eglwyseg ridge are seldom in a good state of preservation. In the Lower Brown Limestone *Productus comoides* is the most abundant, but it is difficult to find a specimen with both valves. The minute crustacean *Leperditia suborbiculata* is also abundant, in brown shales about the middle of the subdivision, north of the Tynant ravine. The most frequent species are given at page 178†, though they are all in a very imperfect condition.

In the Lower White Limestone *Productus cora* is the most common species, and fragments of the large *Euomphalus rugosus* (not *tabulatus*) are of frequent occurrence, so that these two species may be considered the most characteristic. In the Upper White Limestone the fossils are few in both species and individuals, but *Productus cora* is the most frequent. A list of the

* *Endothyra ammonides* and *Textularia*, sp. occur in the Upper Grey Limestone.

† *Productus punctatus* was entered in the list by mistake, and printed in some of the copies, but I have not found it in this subdivision.

ordinary species found in each subdivision is given at pages 183 and 185.

In the Upper Grey Limestone the greatest number of species occur, many being exceedingly abundant, while others are very rare, though most of the latter are common in other localities. The Zoophyta and Brachiopoda are the most abundant, and the specimens sufficiently perfect for accurate determination. In the highest beds *Productus latissimus* and *P. giganteus*, with the corals in the list of characteristic species at page 188, occur in profusion. *Orthis Michelini*, *O. resupinata*, and *Strophomena analogo* are rare, though the first-named *Orthis* is very common at Chirk and other localities to the southward. The Monomyaria, Dimyaria, Gasteropoda, and Cephalopoda are each represented by a few specimens of each species—often by single examples as *Natica tabulata*—but they are usually in such a bad condition that the determination has often been difficult and sometimes uncertain. *Sanguinolites clava* occurs in a fine state of preservation, and is a characteristic species in the subdivision. The Echinodermata is represented by a few ambulacral plates of *Archæocidaris Urii* and numerous stems of *Poteriocrinus crassus;* and the Crustacea by *Griffithides longiceps* which occurs in black shale about 75 feet from the base of the subdivision in Wright's quarry near the limekiln.

This list is the result of frequent visits to Llangollen, extending over a period of seven years. A few other species, including *Productus sub-lævis*, have been referred to the locality, which I have not found myself, and consequently excluded from the list.

HAFOD-Y-CALCH, NEAR CORWEN.

The outlier of Carboniferous Limestone at Hafod, near Corwen, is about seven miles from the same formation at the Eglwyseg ridge, near Llangollen. The area is coloured on Mr. Greenough's Geological Map of England and Wales published in 1819. It also appears on the map prefixed to Prof. Sedgwick's Memoir "On the Older Palæozoic Rocks of North Wales," *Jour. Geol. Soc.*, vol. i., 1845. Although it does not appear on the Map of North Wales appended to Mr. D. Sharp's paper, "Contributions to the Geology of North Wales," *Jour. Geol. Soc.*, vol. ii., 1846, it is described by him in that communication under the head of "Outlier of Mountain Limestone at Guerelas, West of Corwen." He says it is "about half a mile long and a quarter of a mile wide," and that "it is well exposed in open quarries, and consists of thick beds of light grey limestone, alternating with dark and black argillaceous shale, agreeing in character with shale that, in the neighbouring districts of Mountain Limestone, is found in the lower part of that formation." The author states that he "obtained from these quarries many well-known fossils of the Mountain Limestone," and that the strata "dip to the north-east, from a low angle up to 45°. In Sir R. I. Murchison's Geological Map of England and Wales (Society of Useful Knowledge), 1843, the Hafod outlier is omitted; perhaps it is to be found in the more recent editions, unless it is too small to be represented; and I need scarcely say that it is inserted on the Geological Survey and more recent maps.

Prof. Jukes, in the *Geological Magazine* for 1865, vol. ii., p. 186, states that "the patch of Carboniferous

Limestone near Corwen, together with the Flintshire escarpments, makes it almost certain that the whole Carboniferous formation spread formerly over the greater part of North Wales, with just a few island-peaks of older rocks, perhaps, rising up through it;" and there is a letter in reply from Mr. D. C. Davies, headed "The Outlier of Carboniferous Limestone near Corwen," containing a section of the strata and the following list of fossils:— *

Rhynchonella	in the Black Shale.
Chonetes, &c.	
Productus giganteus	in the Limestone.
Phillipsastræa radialis	
Lithostrotion junceum	
Do. fasciatum	
Diphyphyllum latiseptatum (?) and small *Producti* and *Terebratulæ*.	

After describing the strata, he says that "the beds quarried at Corwen correspond to those in the *upper portion* of the main band; the dirt and shale-beds, together with the fossils found all serving to confirm the identity." "The beds are perched up at very great angles; the lower beds are not worked, but, by measuring the outcrop of the strata, it is evident that we have the whole series of beds as developed in the main band" —that is at Llangollen.

Mr. Davies then gives his opinion regarding the deposition of the strata in "a little inland sea," in consequence of which a letter from Prof. Jukes appeared in the same magazine, p. 326, headed "The Outlier of Carboniferous Limestone near Corwen." After disposing of Mr. Davies's theory, he added some remarks and rough

* *Geol. Mag.*, vol. ii., 1865, p. 283.

diagramic sections of interest regarding the Hafod strata. He states: "The country around Corwen was examined by Mr. Talbot Aveline and myself, who spent many pleasant but laborious months in it, so that not only was no rock-exposure unknown to us, but there was hardly a boulder with which one or other of us could not claim a personal acquaintance. If, therefore, our conclusions are wrong (and I, for one, utterly abjure all pretension to infallibility), it is not that we spared our labour in examining the ground, and collecting data for arriving at them." After some descriptions of his sections (woodcuts), he says:—"It is, therefore, a by no means improbable supposition that the preservation of that little patch near Corwen is due to the joint action of the downthrow of the (great Yale and Bala) fault, and a local basin-shaped depression of the beds there. An undulation in the beds at that particular spot perhaps enabled the fault to bring down higher beds than it did just north of it." No opinion is given regarding the position of the Hafod beds in the Eglwyseg ridge, or nearest Mountain Limestone.

The last paper on the subject seems to be the one by Dr. Ricketts, F.G.S., read before the Liverpool Geological Society, and published in abstract, 1866, vol. i, "On the Outlier of Carboniferous Limestone, near Corwen, N. Wales." He refers to the different degrees of dip first described by Mr. Sharp, F.G.S., and supports Prof. Jukes' opinion that a synclinal curve occurred prior to the faulting of the strata, but gives no list of fossils.

The thickness of the Carboniferous Limestone in North Wales varies in different localities in consequence of the undulating surface of Silurian upon which it rests, and the variation in the most extreme cases exceeds 1,000 feet. There can be no doubt that the limestone of Hafod was deposited on the same open

Carboniferous sea as that at Llangollen, and that denuding influences have caused the separation. The actual base of the limestone at Hafod is not exposed, neither can its relation to the Silurian strata be seen. At the south-west boundary of the area the lowest visible limestone occurs in an old though disused quarry just behind some cottages, Plas-uchaf, on the Turnpike road. The limestone is of a light colour, contains *Euomphalus* sp. and *Productus cora*, and closely resembles the Lower White Limestone of Llangollen. The strata seem to dip at 70° S.W., but the exposure is too obscure to render the observation satisfactory, and the occurrence of a fault between the limestone and the Silurian seems probable. Just beyond where the limestone abruptly terminates along the south-west margin of the area, behind the cottages referred to, the drift and surface soil become thicker, and no rock is visible, but the numerous embedded fragments of slaty rock indicate the presence of the Silurian strata beneath. The Lower White Limestone can also be seen on the side of the road in front of the cottages, and it is exposed on the grounds in front of Plas-isaf, the residence of Mrs. Lloyd, where it has evidently been worked, but there is nothing known of any limestone under the house, as shown on the Geological Survey Map.

There is no exposure of any limestone south-west of the places referred to, so that the Lower Brown Limestone of Llangollen does not appear to occur, and there certainly is no exposure of it, at Hafod. The surface of the ground slopes from the centre of the limestone area in every direction, except the south-west, where it rises and forms the hill Cefn Mawr, 200 feet above the Alwen. The area is covered with drift, except at the quarries and rock exposures described; everywhere else the horizontal

beds of sand and gravel obscure the underlying strata from view—even the ends of the limestone strata on the strike are covered by the drift, although there is a rapid descent of about 100 feet in each direction.

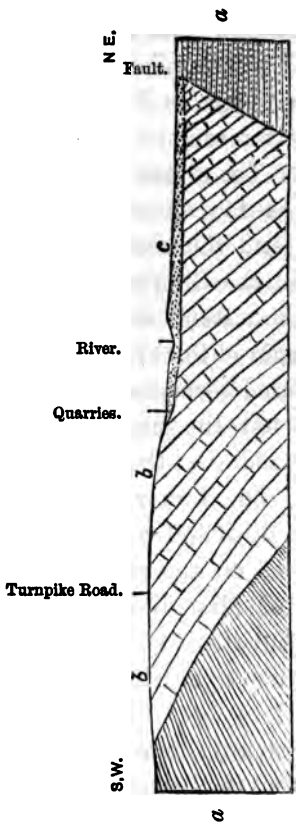


FIG. 5.—HAFOD SECTION.

(*From Geological Survey, Section No. 39.*) Scale, 6 inches to 1 mile.
Length, 1,175 yards.
c. Drift. *b.* Carboniferous Limestone. *a.* Silurian.

The Section of the Geological Survey, Fig. 5, is drawn on the scale of six inches to the mile, and shows the outcrop of the Carboniferous Limestone to extend about 1,000 yards; the average dip of the strata being 45° N.E. and the thickness 2,000 feet, with the upper beds terminating against the Yale and Bala fault.

According to the Geological Survey Map, Sheet 74, S.E., the limestone does not extend so far to the north-east,—not beyond the Alwen.

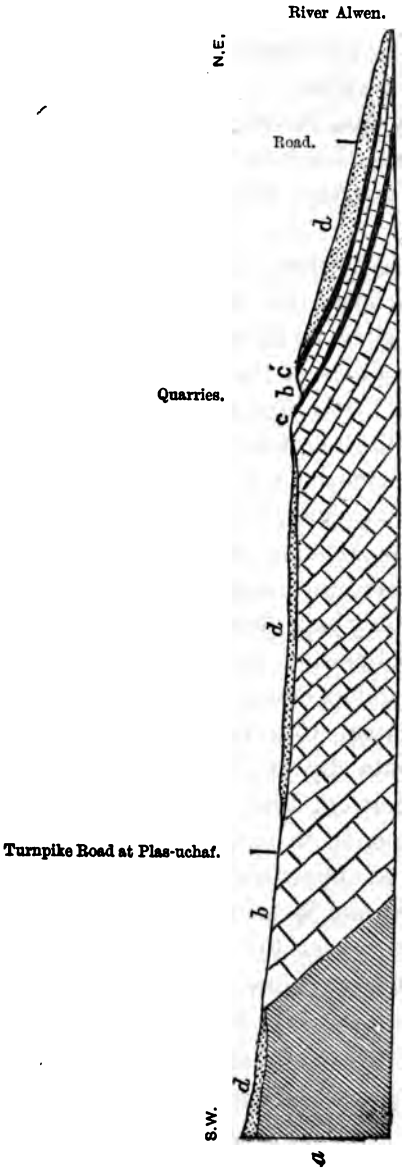


FIG 6.—HAFOD SECTION.

Scale, 24 inches to 1 mile. Length, 440 yards.

a. Silurian. *b*. Carboniferous Limestone. *c* and *c'*. Shale. *d*. Drift.

The Section Fig. 6, is on the scale of 24 inches to the mile, showing the outcrop of the limestone to extend about 400 yards; the average dip to be 45° N.E., and the thickness 750 feet. The line of this section is directly across the strike, whereas the Survey section deviates to the extent of about 30 degrees.

The section given by Mr. Davies in the *Geological Magazine* seems merely intended to exhibit the limestone strata in and about the quarries, where it is burnt for agricultural purposes.

It is evident from these sections that it is difficult to estimate the entire thickness of the Carboniferous Limestone at Hafod-y-Calch, for there is not only an uncertainty about the position of the lowest beds, but according to the Section of the Geological Survey there is a considerable extension of the limestone upwards under the alluvial deposits on the north-east of the Alwen, although unsupported by the Survey Map. Possibly when the district was surveyed by Messrs. Jukes and Aveline there may have been some other exposures visible, but though I have very frequently been over the ground I have not been able to find any limestone in situ on the north-east of the river, and therefore conclude that the map is more reliable than the section. Close to the bridge, on the south-west side, the strata dip at the angle of 20° or 25°, as shown on the section, Fig. 6, and the numerous blocks of limestone on both sides of the river are evidently derived from these upper beds. However, both the Geological Survey Map and Section seem to extend the Carboniferous Limestone too far to the south-west, and it seems improbable that there is limestone beneath Mrs. Lloyd's residence; indeed, the late Mr. Lloyd informed me that none had been observed below the drift, which is of considerable thickness. Still, it is probable that the

geological surveyors had some reason for concluding that the limestone existed beyond where I have been able to find it, though, after a careful examination of the area, I have concluded that the Lower White Limestone is either faulted against the Silurian on the south-west, or that it reposes directly on the Silurian rocks, the Lower Brown Limestone being absent.

The thickness of the Carboniferous Limestone at Hafod-y-Calch, including the Lower and Upper White Limestone and the Upper Grey Limestone, as described in the Eglwyseg ridge at Llangollen, seems to be about 750 feet, but the subdivisions cannot be separately measured. The limestone worked in several large quarries is all on the same horizon and is about 80 feet in thickness, including interstratified shale. The lowest band of rubbly limestone and black shale (*c*) is about 6 feet thick, and it is from this bed and the thin bedded limestone below that the numerous fossils have been obtained; collecting being much facilitated by the great inclination of the beds and the extent of the surface exposed. Hafod is one of the most prolific localities for fossils in North Wales, being remarkable for the profusion of individuals, the number of species, and the perfect condition in which they occur; and from its frequent mention as a locality must for a long period have yielded the beautiful corals, particularly *Phillipsastrea radiata*, for which it is celebrated. This and most of the fossils in the list are common in the beds just below the dark band *c*. The fossils indicate that the strata in which they occur belong to the Upper Grey Limestone, and most probably the upper beds in the subdivision. Some, however, viz., *Stroparollus costellatus*, *Orthis Michelini*, and *Alveolites septosa*, have only been observed lower in the series, but taken collectively the fossils are remarkably similar to

those found in the highest beds of the Upper Grey Limestone at the Eglwyseg ridge. The highest strata at Hafod are about 50 feet of thick bedded white limestone, succeeded by 10 feet of shale and rubbly limestone (*c'*), it being very improbable that there are any higher Carboniferous strata on the north-east of the Alwen.

Although the fossils in the following list, from the limestone and shale in the quarries at Hafod, are on the horizon of the top of the Upper Grey Limestone, the lithological characters of the strata do not present much similarity to that subdivision. The band of dark limestone and black shale (*c*) is very similar, but the overlying 50 feet of limestone is much thicker and of a lighter colour than any corresponding beds in the Eglwyseg ridge. The strata seem to have altered with the distance, and no minute co-ordination of the particular beds can be recognised. That the 50 feet of white limestone represents the Sandy Limestone seems to be unlikely, for it is succeeded by shale and thin beds of rubbly limestone. The limestone about Plas-uchaf is very similar to the Lower White Limestone near Llangollen, and is evidently on the same horizon.

LIST OF FOSSILS FOUND AT HAFOD-Y-CALCH.

PISCES.

1 *Pscphodus* sp.

HETEROPODA.

2 *Bellerophon cornu-arietes*, Sow.
3 ,, *tenuifascia*, Sow.

GASTEROPODA.

4 *Stroparollus costellatus*, M'Coy.
5 *Natica ampliata*, Phil.

DIMYARIA.

6 *Modiola* sp.

BRACHIOPODA.

7 *Orthis Michelini*, Koninck.
8 *Productus cora*, D'Orb.
9 ,, *giganteus*, Mart.
10 ,, *fimbriatus*, Sow.
11 ,, *longispinus*, Sow.
12 ,, *Martini*, Mart.
13 ,, *punctatus*, Mart.
14 ,, *semireticulatus*, Mart.
15 *Rhynchonella pleurodon*, Phil.
16 *Spirifera bisulcata*, Sow.
17 ,, *crassa*, Koninck.
18 ,, *glabra*, Mart.
19 ,, *lineata*, Mart.
20 *Streptorhynchus crinistria*, Phil.
21 *Strophomena anologa*, Phil.
22 *Terebratula hastata*, Sow.

BRYOZOA.

23 *Fenestella fastuosa*, Koninck.
24 ,, *membranacea*, Phil.

ECHINODERMATA.

25 *Archæocidaris Urii*, Flem.
26 *Poteriocrinus crassus*, Koninck.

ZOOPHYTA.

27 *Alveolites septosa*, Flem.
28 *Chætetes tumidus*, Phil.
29 *Clisiophyllum bipartatum*, M'Coy.
30 ,, *Keyserlingi*, M'Coy.
31 ,, *turbinatum*, M'Coy.

32 *Cyathophyllum regium*, Phil.
33 *Lithostrotion irregulare*, M'Coy.
34 ,, *junceum*, Flem.
35 ,, *Portlocki*, M. Edw.
36 *Lonsdaleia rugosa*, M'Coy.
37 *Phillipsastrea radiata*, M. Edw.
38 *Syringopora ramulosa*, Phil.
39 *Zaphrentis cylindrica*, Scouler.

FRON-Y-CYSYLLTE.

At Fron, about three and a half miles to the east of Llangollen on the south side of the Dee, the Carboniferous Limestone occurs in an elevated position, and forms a capping on the hill, with the Wenlock Shale beneath, as shown in the following wood-cut (Fig. 7):—

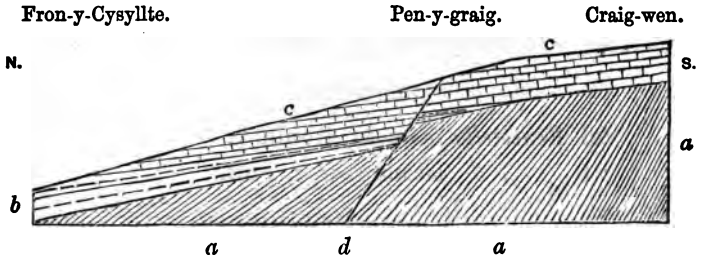


FIG. 7.—FRON SECTION.

d. East and west fault.
c. Upper Grey Limestone.
b. Upper White Limestone.
a. Silurian.

The limestone has been broken up by several faults running north-north-east and south-south-west, and east and west, but particularly by one in the latter direction (*d*), which causes the limestone to present two areas at different elevations, that of Fron-y-Cysyllte

being the lowest, and that of Pen-y-graig or Craig-wen the highest. Both of these areas exhibit the Carboniferous Limestone resting on the underlying Silurian strata in steep escarpments on the north-west of the hill, from which a magnificent view of the Vale of Llangollen is obtained. There are several large quarries, and in one of them, about half way up the hill, the east and west fault referred to is exposed for a considerable length—the limestone having been removed on the north or downthrow side of it. The following is a section exposed in an old quarry close to the Primitive Methodist Chapel at Fron-y-Cysyllte:—

		FEET.
Lower beds of the Upper Grey Limestone.	Limestone thin-bedded..	10
	Limestone	8
	Limestone	3
		21
Upper beds of the Upper White Limestone.*	Concretionary Shale ...	8
	Limestone	2
	Shale	2
	Limestone	7
	Rubbly Limestone	2
	Limestone	7
		28

The lower beds in this section belong to the Upper White Limestone which terminates upwards with the 8-feet bed of concretionary shale, and the 3-feet bed of limestone above it forms the base of the overlying Upper Grey Limestone. This section presents the most considerable exposure of the Upper Grey Limestone, which

* In these beds I found *Alveolites septosa*, a coral not found in the overlying subdivision.

gradually thins out higher up the hill. Two almost continuous sections are exposed along the north-west of the hill, the 8-feet bed of shale being conspicuous in the lower one near the base of the limestone. The upper section along Craig-wen does not present any indication of the 8-feet bed of shale, which seems to have thinned out. There is a large circular quarry at the lower end of the upper area, and the Upper Grey Limestone seems to rest directly on the Wenlock Shale. Mr. Isaac Williams, who worked the quarries many years ago, informed me that the Wenlock Shale is just below the floor of these quarries and the limestone has been removed to its base—the Upper White Limestone being absent—so that the rapid attenuation of the limestone with the rise of the Silurian strata at Fron is evident.

The following is a section of the strata exposed in the upper area, Pen-y-graig or Craig-wen quarries:—

		FEET.
Lower beds of the Upper Grey Limestone.	Dark Grey thin-bedded Limestone...	25
	Light ,, Limestone	10
	Dark Grey thin-bedded Limestone...	50
		85

These beds are above the horizon of the 8-feet bed of shale in the lower quarries, and consequently nearly the whole of the limestone quarried about Fron is from the Upper Grey Limestone. The upper beds have been denuded, so that the strata exposed in the quarries represent the lower beds of the subdivision at Trevor rocks, the band of light grey limestone being about the same distance from the base in both localities.

The Upper Grey Limestone at Fron contains the usual fossils found in the lower part of the subdivision on the Eglwyseg ridge, and the strata are faulted against

the Cefn-y-Fedw Sandstone on the east of the limestone area. The sections exposed at Fron are very important, for they prove that the Carboniferous sea bottom shallowed there, and was much higher than it was three or four miles to the north-west; and that the limestone attained a considerable thickness in that direction before any was deposited over the former area. It seems probable that the country south-west of Fron may have been dry land during the deposition of the lowest limestone on the north-west. This supposition is strongly confirmed by the beds of shale in the Eglwyseg ridge being in some places largely composed of flattish fragments of Wenlock Shale, only slightly rounded, derived from the coast-line of the old Carboniferous sea.

Proceeding towards the south there is an exposure of the Carboniferous Limestone at Bron Freian, where it must be very thin. It is, however, only exposed on the surface of the road through the village, so that little can be seen of it. It is difficult to measure or approximate the thickness, but it appears to be under 100 feet. Whether there is a greater attenuation of the limestone at this place cannot be ascertained with certainty, for neither the base of the limestone nor its juncture with the overlying Cefn-y-Fedw Sandstone is exposed, and it may be faulted. It has been remarked that the diminution in the breadth of the country occupied by the outcrop of the Carboniferous Limestone varies, in consequence of an alteration in the inclination of the strata,* but an examination of the country dispels any such conclusion. There are very few exposures of the Cefn-y-Fedw Sandstone in this locality.

* Excursion to the North Wales Border, "Proc. Geol. Ass.," vol. iv., p. 559.

BRON-Y-GARTH, NEAR CHIRK.

The Carboniferous Limestone probably extends southwards through Chirk Park, though I have not seen any exposure there, but the valley of the River Ceiriog, one and a half miles east of Chirk, presents a fine section through the formation. All the limestone strata belong to the Upper Grey subdivision, and the thickness is about 137 feet. Along the strike of the strata there is another valley, running towards the south-west for about half-a-mile, and the following section is across this valley, with the Bron-y-garth limestone quarries and the overlying Cefn-y-Fedw Sandstone at a higher level on the south-east, as shown in the following wood-cut (Fig. 8):—

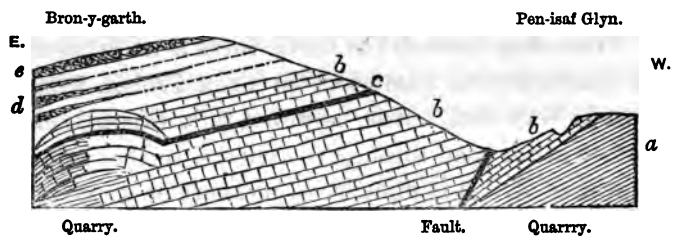


FIG. 8.—BRON-Y-GARTH SECTION.

e. Cefn-y-Fedw Sandstone. *d*. Sandy Limestone.
c. Shale-Bed. *b*. Upper Grey Limestone.
a. Silurian.

The Lower Cefn-y-Fedw Sandstone is exposed in quarries and other sections. It is a yellowish sandstone, and has been used for building purposes. The lower beds are well seen toward the top of the valley, and present the following section in a hillock west of Castle Springs.

		FEET.
Lower beds of the Cefn-y-Fedw Sandstone and Conglomerate.	Soft Sandstone, light colour, with many quartz pebbles.	12
Upper beds of the Sandy Limestone.	Soft Sandstone	10

These beds represent the base of the Lower Sandstone and Conglomerate and the top of the Sandy Limestone, but all differ from the typical strata above the Eglwyseg ridge in being much softer—almost loose sand in some places. Higher beds are exposed along the road above this section, and contain very few pebbles, though nests of sand are frequent, and the rock weathers with a honeycombed appearance.

The Sandy Limestone crops out in the field just above the quarry at Bron-y-garth, and is an impure limestone which has been but little used. These passage beds between the Carboniferous Limestone and the Cefn-y-Fedw Sandstone are not well exposed, so that the sequence of the strata cannot be given.

In the Bron-y-garth quarry the Upper Grey Limestone consists of a series of beds of limestone and shale, the most remarkable being a 12-feet bed of shale. The lowest bed of limestone, 50 feet thick, is said by the quarrymen to rest on some soft clay, with the slate rock —Silurian—beneath, but there is no exposure to prove the statement. At the other side of the valley by Penisaf-Glyn there is a large quarry, the strata in which are same as the 50-feet bed at Bron-y-garth, and the fossils, *Productus giganteus*, *Lithostrotion Portlocki*, and *Syringopora geniculata* are common to both. Between the two quarries there must be a fault as shown on the section, but its exact position is uncertain. Higher up the valley the lower beds of the limestone are faulted against the Lower Cefn-y-Fedw Sandstone, and the continuation of the fault is obvious. In appearance the section across the top of the valley is very different to the one given at the bottom Fig. 8, but the difference is easily explained by the greater denudation of the valley toward the north-east. The locality is very interesting,

for it presents several geological conditions rarely found in such close contiguity.

The following is a section of the whole of the strata from the base of the Carboniferous Limestone to the lower part of the Sandy Limestone, as correct as it has been possible to render it. When the measurements are given the description and thickness are strictly correct. The 12-feet bed of shale is remarkable for the fossils it contains, especially *Leptæna Hardrensis* and *Orthis Michelini*, both of which occur in profusion.

		FT.	IN.	
Lower beds of the Sandy Limestone.	Impure Limestone ...	,,	,,	
Upper Grey Limestone.	Shale	4	0	
	Limestone	4	6	
	Shale	3	0	
	Limestone	10	0	
	Shale	1	0	
	Limestone, thin beds.	3	0	Represent the 15-feet of Shale at Craignant.
	Shale	12	0	
	Limestone	12	0	
	Shale	1	6	
	Limestone	30	0	
	Shale	2	0	
	Limestone	50	0	
	Soft Clay ?	4	0	
		137	0	

The following fossils occur in the 12-feet bed of shale: *Buccinum imbricatum; Myacites sulcatus; Athyris Roissyi; Chonetes Hardrensis; C. papilionacea; Orthis Michelini; Productus longispinus; P. punctatus; P. semireticulatus;*

Rhynchonella pleurodon; Spirifera bisulcata; Fenestella membranacea; Poteriocrinus crassus; Clisiophyllum prolapsum; C. turbinatum, and *Lithostrotion irregulare;* and the following occur in the thick bedded limestone at the base of the formation, viz.:—*Productus cora; P. giganteus; Lithostrotion Martini; L. Portlocki,* and *Syringopora geniculata.*

Still further to the south-west, about a mile from the river there are several small quarries at the top of the valley, "L'stone Quarries" on the Survey Map, where the lowest beds of the Upper Grey Limestone are exposed and the ordinary fossils occur. The limestone contains numerous nests of sand, but although close to the Wenlock Shale, there is no section showing the one resting upon the other.

At Grug-fryn, above half a mile to the south, the Carboniferous Limestone is again exposed, with the Cefn-y-Fedw Sandstone on the east and the Wenlock Shale on the west, and along such a narrow space that the limestone seems to be only 50 or 100 feet thick. The few exposures seem to present the lower beds of the Cefn-y-Fedw Sandstone reposing on the Upper Grey Limestone, but probably there is a fault between them, the 12-feet bed of shale having been denuded, for it occurs in several localities south of this place, and presents the same appearance and fossils as at Bron-y-garth.

CRAIGNANT.

The next section is at Craignant, where there is a fine exposure of the Carboniferous Limestone. The strata belong to the Upper Grey Limestone, and the following is a section of the whole of the beds exposed:—

		FT.	IN.	
Lower beds of the Sandy Limestone.	Impure Limestone...	,,	,,	
Upper Grey Limestone.	Shale	?		
	Limestone	?		
	Shale ..... / Limestone ..... / Thin beds of Limestone	15	0	
	Shale, with beds of Limestone at base.	15	0	Represents the 15-feet of shale and Limestone at Bron-y-garth.
	Limestone	20	0	
	Shale	0	6	
	Limestone	3	0	
	Shale	0	6	
	Limestone	25	0	Base not exposed.
		74	0	

This section closely resembles that near Chirk, and the occurrence of the 15-feet bed of shale with the same species of shells and corals as at Bron-y-Garth is very remarkable.

The following fossils occur in the 15-feet bed of shale, viz.: *Chonetes Hardrensis; C. papilionacea; Orthis Michelini; O. resupinata; Productus longispinus; Spirifera bisulcata; Rhynchonella pleurodon; Poteriocrinus crassus; Chætetes tumidus; Cyathophllum Murchisoni.*

The general order of the strata is so similar that it may be considered conclusive evidence that the upper beds of the Upper Grey Limestone were deposited continuously over the intervening country, though they have been denuded and only the lower portion of the subdivision left exposed. The thickness of the Upper Grey Limestone at Craignant, as shown in the section, is about 74 feet, and it is not likely that the actual thickness is much greater, for it includes the whole of the outcrop. It seems that the Silurian rocks on the west of the country described formed land during the deposition of the lowest Carboniferous Limestone, and that it was only after a lengthened subsidence that some of the upper beds were deposited along the old coast line. There is no reason to suppose that the country further west, about Glen Ceiriog, was ever covered by the limestone, though it seems probable enough that the Cefn-y-Fedw Sandstone and Coal Measures may have extended over it.

The succession of the strata from the Carboniferous Limestone up to the Cefn-y-Fedw Sandstone cannot be seen in detail about Craignant. The limestone at the top of the quarry is covered with drift, but probably some shale comes in, and then the Sandy Limestone, which can be seen on the dip of the strata, at a lower level, about 200 yards along the road to the east. The Sandy Limestone has been worked and evidently burnt for lime, and it must occur just over the upper beds in the section, being immediately below the Lower Cefn-y-Fedw Sandstone and Conglomerate, which rises to the south and forms the bold outline of Sclattyn Hill.

[*To be continued.*]

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* Have read Papers before the Society.

† Contribute annually to the Printing Fund.

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PROCEEDINGS

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PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION NINETEENTH.

OCTOBER 9TH, 1877.

THE PRESIDENT, HUGH F. HALL, F.G.S., in the Chair.

The President read the Annual Address.

NOVEMBER 13TH, 1877.

THE PRESIDENT, HUGH F. HALL, F.G.S., in the Chair.

WILLIAM HEWITT, B. Sc., JOSEPH J. ROBINSON, and HENRY YOUNG were elected Ordinary Members.

The following communication was then read:—

ON THE GEOLOGICAL SIGNIFICANCE OF THE CHALLENGER DISCOVERIES.

BY T. MELLARD READE, C.E., F.G.S.

No knowledge can be more interesting than that which connects us with the past—which attempts to bring the sequence of events in an unbroken history from the earliest geological period to the present time. As a contribution towards the geological history of the world, the discoveries made during the three years' voyage of the *Challenger* have a special significance.

Although the scientific staff are still engaged in formulating the results of the observations, and naturalists in this and other countries are studying the forms of life brought up from the ocean depths, I trust it will not be considered premature and presumptuous of me to call attention to some of the physical problems of geology affected by the remarkable facts which have been now for the first time brought to light.

Without going minutely into details, which can be best studied in the Admiralty Reports* and the Reports to the Royal Society†, it appears to be pretty clearly established that there is a definite relation between depth and temperature throughout the ocean, obscured, it may be in some cases, by local circumstances, but, on the whole, remarkably general and uniform.

Excepting in depths of between 100 and 200 fathoms and under the exceptional circumstances produced by the melting of the Antarctic Ice, the water decreases in temperature from the surface to the bottom. In the North Atlantic ranging from above 70° Fah. at the surface to 35° at 2,000 fathoms, continuing at 35° for the greater depths, which reach, in some cases, over 3,000 fathoms. In the South Atlantic the lowest temperature is 31° in what is called the Western tongue of the Atlantic basin; the lowness of the temperature, it is supposed, being due to an indraught of the Antarctic waters. The temperature sections, to my mind, reflect the greatest credit on the Admiralty and their officers; they are the work of careful practical men, who have not allowed theory to run away with them, and evince a commen-

* "H.M.S. *Challenger's* Reports on Ocean Soundings and Temperature," Nos. 1 to 7.

† "Reports from the *Challenger*."—Proc. of Roy. Soc., vol. xxiv., *p. 463* to p. 636.

dable common-sense and scientific grasp of the subject. So regular, however, do they find the results of their temperature soundings, that if in any special cases the minimum is reached at a certain depth and below that the water is uniform in temperature, they assume that it is cut off from the general oceanic basin by ridges at a depth approximately the same as that at which the same temperature is found in the general ocean. This is the case with the Celebes, China, and Japan seas, which, if raised above the general ocean, would, in fact, become lake basins or inland seas.

Now, this lowering of the bottom temperature over such immense areas is certainly a remarkable and unexpected fact, and shews that the secular cooling of the earth must be extremely slow, as to all appearances contact with the bottom does not in any case appreciably influence the temperature of the bottom water.

The water is heated at the Equator and cooled at the poles, but the rate of interchange is unknown, and probably very slow. No undercurrents at great depths are recorded. Of course all currents from the Equator to the poles must come back in some form or other, but the greater bulk of water is just as likely to return in undercurrents at small depths as by a general movement of the whole depth of ocean water. The materials for making an exact calculation do not exist, but I am inclined to think the indraught of bottom water from the poles is decidely slow. The heaviest water, always the coldest, excepting it be more saline, necessarily keeps to the bottom, and when we find that contact with the bottom does not influence the temperature of water that has travelled many miles from the poles to the Equator, we must pronounce it to be an interesting and unexpected

fact.* Not less remarkable is the fact that, after penetrating the surface waters of the Equator, the colder temperatures are reached nearer the surface than in more northern latitudes.

Thus we see the conditions of increase of temperature in the ocean are the reverse of those on the land. All investigations of underground temperature show a gradual increase of heat as the earth is penetrated, so that if we take it at 1° per 60 feet,† at 3,000 fathoms (the depth of part of the Atlantic), the temperature of the earth at that depth, with the surface of land at the sea level would be—allowing 55° as the normal of the surface—355°, or more than half as high again as boiling water at the surface, while at the same zone beneath the Himalayas it would not be less than 600°. The influence of surface heat and cold extends therefore, by convection, to the greatest depths of the ocean, while on land it is limited by conduction to about 80 feet. What influence on climate this great body of ice-cold water can have it would be difficult to say, but it certainly must make itself felt, and in all speculations on changes of climate the effect of former shallow or enclosed seas must not be

* Mr. Mallet, in the "Introduction" to his translation of Professor Palmieri's Eruption of Vesuvius in 1872, says, p. 67:—"By application of Fourier's theorem to the observed rate of increment of heat in descending from the Geothermal *couche* of invariable temperature, and the co-efficients of conductivity of the rocks of our earth's crust, as given by the long-continued observations made beneath the Observatories of Paris and Edinburgh, it results that the annual loss of heat into space of our globe at present is equal to that which would liquefy into water, at 32° Far. (0°C), about 777 cubic miles of ice." This would equal a film of ice all over the globe ·25 of an inch thick, or say 1 yard deep of fresh water raised 1° Far.

† I do not consider this by any means established, the increase varies greatly in different localities, and also with the nature of the rock. See my "Age of the World, as viewed by the Geologist and the Mathematician."—*Geo. Mag.*, April, 1878.

lost sight of. It is also quite clear that the tendency of the spreading of the cold water of the poles over so large an area of the globe must be to ameliorate the climate of the poles as its place is taken by water of a higher temperature, and it would thus seem that the great depth of the Atlantic and Pacific Ocean is a means of equalizing the temperature of the globe. In addition to the climatic effect of the geographical distribution of land and sea, the actual form and depth of the ocean bottom is a factor that has not been previously considered.

Not the least interesting of the facts brought to light by the *Challenger's* work is the distinctive character of the deposits in relation to the depth. The extended deposits of Red clay which are found to fill up most of the basins below 2,000 fathoms, * and the accompanying nodules of per-oxide of Manganese are discoveries of great geological importance. They not only show that chemical changes are taking place, previously unsuspected, but the nature of the deposit is pointed to as an indication of the great age of the present oceans. Of course, it is impossible to tell the thickness of this Red clay, but if Mr. Murray's explanation be the correct one, and it is the most reasonable yet advanced, the deposit is the result of the decomposition of volcanic products.

Who, I ask, would have suspected so large an area of the globe to be coated with matter emitted from volcanoes? The rate of accretion must have been extraordinarily slow, as the area covered by the Red clay, compared with volcanic ejections contributed annually direct to the ocean, supplemented, even as Mr. Murray suggests, by the denudation of ancient volcanic deposits on land, is so very great.

* Mr. J. Murray, on Oceanic Deposits.—"Proc. of Roy. Soc.," vol. xxiv. p. 527.

The Globigerinæ ooze, first discovered by the "Porcupine" soundings as an extensive oceanic deposit, gradually shades off into the Red clay, and usually finally disappears at about 2,000 fathoms.* Now, there is no reason to suppose that the pumiceous matter is not deposited in moderate as well as great depths, and the inference therefrom is that it is obscured by the quicker accumulation of Carbonate of Lime from the tests of Foraminifera, in depths of less than 2,000 fathoms, at about which point the two deposits usually blend. As reinforcing the argument of its age, the profusion of sharks' teeth and ear bones of cetaceans found in the Red clay has been justly dwelt upon. If we assume that foraminiferal organisms (with calcareous tests) remove annually from sea water the same amount of Carbonate of Lime as is contributed by rivers from the land, we have a rough mode of arriving at the rate of accumulation of Globigerinæ ooze.

In my address on "Geological Time," which I had the honour to read to this Society, I estimated the average amount of carbonate of lime annually removed from each square mile of land surface over the whole globe at 50 tons.†

* In an exceptional case it was found at 2925 fathoms in the Mid-Pacific—the depth at which it is found is variable within certain limits. —Mr. J. Murray—"Proc. of Roy. Soc.," p. 525.

† It is fair to assume that the amount of Carbonate of Lime in the sea remains pretty constant, otherwise it would soon be all used up, as there is only sufficient in the sea to cover it to a depth of 4·5 feet. See Address on "Geological Time." I omit Sulphate of Lime from consideration, because if organisms can decompose it, which is a moot point with naturalists and chemists, it must be in a small degree, otherwise the sulphate would not form, as it does, the bulk of the lime in the ocean, it being contributed by the land only, at the rate of 20 tons per square mile per annum, according to my approximation. Being used up slowly, it accumulates more rapidly.

"Geological Time."—Presidential Address to the Geo. Soc., Session 1876–7; p. 21 in reprint.

At 15 feet to the ton the weight of compact limestone, this would give a uniform deposit over the whole ocean of ·0000094 of a foot per annum, but if considering the deposit as one of loose mud holding much water, we assume it to accumulate at three times that rate, it would give ·0000282 of a foot per annum, or, in round numbers, 35,500 years for a deposit of chalky mud 1 foot in thickness. If, however, we say that calcareous deposits are absent where the Red clay is present, and the whole of the Carbonate of Lime from the land is used upon the remaining area, we may reduce the period to 20,000 years. These calculations are made quite independently of any deposit of coarser materials, because they do not, as a rule, exist, except in the form of volcanic products at the depth affecting my argument. Of course, in shallower water the deposits increase much more rapidly by the admixture of other materials.

We thus find that the maximum average rate of accumulation cannot be more than 1 foot of calcareous ooze in 20,000 years,* but probably it takes much longer for that thickness to be deposited; for we may not unnaturally surmise that coral animals and molluscs remove more lime from sea water, area for area, than the minute Foraminifera. Locally, the deposit may take place more rapidly, but what is deposited in one area is robbed from another area, and I think we may safely assume that not more carbonate of lime is used up

* Professor Martin Duncan, F.R.S., says of deep sea deposits, in his "Presidential Address to the Geological Soc. of London," vol. xxxiii., p. 74—"I have satisfied myself from late researches that the rate of deposition is extremely slow. Thus an electric cable was laid down in the *Globigerinæ* ooze regions, and five years after a considerable coral growth had taken place on it. Some of these living calices were close above the cable, and, therefore, the deposit had been infinitesmal in that time."

annually than what is contributed annually by the land; otherwise, the quantity in the sea would finally, before this, have become reduced to nothing.* These forces of nature, in my opinion, tend to balance each other.

Where the Globigerinæ ooze ends the Red clay begins —the one shades into the other. Pumice and the materials of the Red clay are found in the ooze, and more abundantly as the Red clay is approached; hence the scientific men of the *Challenger* were driven to the conclusion that the Red clay is found in the greater depths because in them the tests become destroyed by carbonic acid before reaching the bottom.

If, then, it takes 20,000 years for an average thickness of one foot of chalky mud to accumulate over the area occupied by it, how long a period will be required for one foot of Red clay?—the mind stands aghast at the problem. Probably 10 times as long.† Certainly the volcanic emissions annually directly deposited in the sea, combined with those due to denudation, must be excessively small compared to the amount of carbonate of lime annually contributed by the whole surface of the

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* Mr. Murray says ("Proc. of Roy. Soc.," vol. xxiv., p. 531): "When there has been no reason to suppose that the trawl has sunk more than one or two inches in the clay, we have had in the Bag over a hundred shark's teeth and between thirty and forty ear-bones of cetaceans; some of them have been imbedded in over an inch of the Manganese arranged in concentric layers, while others have had just a trace of Manganese on them, or none at all. . . . In the *Globigerinæ*, Radiolarian and Diatom oozes we have found during the whole cruise only one or two shark's teeth and perhaps one tympanic bone. In shore deposits they were even more rare. These facts, taken with others that will at once suggest themselves, go to show, as might be expected, that the shore deposits accumulate faster than the organic oozes, and these last faster than the deep sea clay."

† See Geological Time before quoted.

Land. Not only does Geology tell us this, but the arrangement of the deposits in the sea also tells us the same thing.

The nodules of per-oxide of Manganese, and the profusion of sharks' teeth both point to the same conclusion, and it is not to be wondered at if some Geologists are almost ready to believe that our great oceans, from the beginning of geological time, have always been as they are now. It has been said that this Red clay deposit has no equivalent in any of the known rocks, and this is used as another argument. *

While believing that the ocean depths are of enormous age, it is impossible to resist other evidences that they have once been land. The very continuity of animal life on the globe points to it. The molluscous fauna of the Eastern Coast of North America is very similar to that of Europe, and this could not have happened without littoral continuity, and at no very distant period, geologically speaking; yet there are depths of 1,500 fathoms between these continents. Again, the form of the bottom of the North and South Atlantic is so like a continuation of the land; the Dolphin, Challenger, and Connecting Ridges follow so naturally the outlines of the continents they lie between, that it is difficult to believe they have not been formed by sub-aerial denu-

* The President of the Royal Soc., Dr. Hooker, stated ("Proc. of Roy. Soc.," vol. xxv., p. 354) that Mr. Sorby informed him that a microscopic examination of the "Red Clays" showed them to be, in composison, like the Gault. This is singular, as the Gault is associated with the chalk, but where are the pumice stones and per-oxide of Manganese? On the other hand, Mr. J. Starkie Gardner believes the Gault to be a shallow water deposit.—*Quar. Journ. of Geo. Soc.*, vol. xxxiii., p. 206.

dation—that they are not, in fact, valleys and mountains.*

The probable causes of these subsidences and upheavals I am at present engaged in investigating; so I will not touch upon them now, but will simply confine myself to a consideration of the significance of the alleged absence of rocks corresponding to the Red clay deposit of the ocean.

In the first place, we are not by any means prepared to prove a negative. With so much of the area of the Globe unexamined geologically, he would be a bold man to declare that equivalents in the Earth's crust do not exist. Again, if they do exist, it would probably be in sporadic patches, for any one acquainted with sub-aerial denudation will know what havoc the rain and weather would make with a thin coating (like the deposit in question would probably be), unless protected by denser deposits above. Of all the dangers that beset a geologist, that of reasoning from the absence of an expected thing is the worst, as conclusions are so readily based upon it. Again, it is quite within the bounds of possibility it may turn out the true explanation that seas of the depth of over 2,000 fathoms never existed on the sites of our present continents. It is quite consistent with the supposition that the extreme depths of the ocean may at one time or other have been dry land—that only shallow seas or seas of moderate depth may have at the same time flowed over portions of the present continents. The ocean depths may thus prove to be *relatively* permanent indentations. Certainly the character of the rocks,

* Mr. Judd says, speaking of these ridges: "Hence it is not difficult to picture to ourselves the existence in later Tertiary times of a great band of volcanic peaks, comparable in magnitude and parallel in position with the range which now forms the western boundary of the great American continent."—"Contributions to the Study of Volcanos," *Geo. Mag.*, 1876.

generally composed so largely of sediments, would rather tend to confirm this view. If we consider the Globe in its present form as liable to equal subsidences and upheavals over large areas, it follows that an upheaval bringing the present Atlantic bottom 400 fathoms nearer to the surface, balanced by an equal subsidence in Asia, would lay a great area of land under water without affecting the Atlantic as an ocean to any material extent. As so clearly shown by Darwin 30 years ago in respect to South America,* there are general and tolerably equable upheavals, extending for thousands of miles, occurring independently of the actual fracturing of the Earth's crust, so that it is extremely probable that the deposits over continental areas may be greater, more fluctuating and variable in character than those which take place over the areas now occupied by the oceans.

The time has not yet come for taking a comprehensive view of the bearings of this recently acquired knowledge of the ocean depths: that must be deferred until all the information is published; and facts are so interlocked and dependant for their thorough comprehension on classification, system and arrangement, that until each specialist has finished his work it were impossible to generalise with complete success. Sufficient is known to enable us to say the work of the *Challenger* will be an important contribution to natural Science, and of the greatest value in assisting to solve some great and enthralling problems of the Earth's history, the interpretation of which has been reserved for the present age.

* "Geological Observations": We have seen that upraised marine remains occur at intervals, and in some parts almost continuously, from lat. 45° 35′ to 12° S along the shores of the Pacific. This is a distance in a North and South line of 2,075 geographical miles." "Judging from the upraised shells alone, the elevation in Chiloe has been 350 ft., at Conception certainly 625 ft., and by estimation 1,000 ft.; at Valparaiso 1,300 ft," &c.—Sec. Edit., p. 276.

DECEMBER 11TH, 1877.

THE PRESIDENT, HUGH F. HALL, F.G.S., in the Chair.

PATRICK M. COOGAN, C.E., was elected an Ordinary Member.

The following communications were read:—

ON EXAMPLES OF SUB-AERIAL EROSION DURING INTERVALS IN THE DEPOSITION OF THE CARBONIFEROUS LIMESTONE.

BY CHARLES RICKETTS, M.D., F.G.S.

NOTES OF CHRYSOCOLLA.

BY WILLIAM SEMMONS.

SITUATE on the Triassic rocks, with frequent coverings of the Boulder-clay, Liverpool seems completely shut out from any relation with mineral deposits. Its extensive commerce, however, sometimes affords collectors opportunities for acquiring valuable specimens from foreign lands, and the following notes were prompted by observations on some heavy arrivals of Copper Ores from Lower California. These ores were of a very remarkable character. They consisted almost wholly of Chrysocolla, and the carbonates of copper, which generally accompany this mineral, were present only to a very minute extent. When Carbonate was present, it was always as "Azurite," the blue variety. Occasionally a little chloride of copper, "Atacamite," was found, interstratified with gypsum, *&c.*; both these two compounds being formed in the

neighbourhood of volcanoes, might point to igneous action being connected with the deposits. The other associated minerals, Kupferfrechez (see Trans. L'pool Geol. Soc., 1876–7, p. 282), &c., are not within the purpose of the present paper.

The remarkable varieties of Chrysocolla met with, and their peculiar behaviour before the blow-pipe, induced me to compare them with varieties from Chili, Peru, Cornwall, and other localities. The results to which I have been led are stated at the end of this paper, and I will, in the first place, give a brief description of the several varieties I have found.

No. 1, FROM LOWER CALIFORNIA.

This large stone shows strikingly a series of gradations from the light earthy variety of Chrysocolla, with hardness 1, to the vitreous variety, hardness 5. Beautiful dendritic formations of manganese ore are scattered throughout the specimen, and Kupferfrechez is also present. Commencing with the vitre us variety, we find it of a dark, blueish green colour; this passes gradually into a lighter shade, until we reach a variety with the faintest tinge of blue green, almost white. The light-coloured variety is quite adherent and fuses in blow-pipe flame, while the dark-coloured variety (typical Chrysocolla) is quite infusible, and is non-adherent. Thin veins of the vitreous variety permeate the other, and a layer of chalcedony covers them both; this, in its turn, is covered by a layer of calcite crystals.

No. 2 (SAME LOCALITY).

Similar to the light earthy variety described above, but so porous that it floats on water. Colour, light blue green; hardness, 1 to 1½. Remarkably absorbent of

of water, and when saturated becomes of a much darker colour. Fuses before the blow-pipe. Mr. W. M. Hutchings, F.I.C., whose assistance in these examinations I would here acknowledge as being of the highest possible value, has analysed this variety with the following result, which I have placed for comparison with an analysis made, by the same gentleman, of the hard and vitreous variety from No. 5.

	VARIETY, Hard and Vitreous.	VARIETY, Soft and Earthy.
$Si\ O_2$	67·07	46·45
$Cu\ O$	24·95	39·15
$Pb\ O$	·26	·41
$Fe_2\ O_3$	·27	·48
$Al_2\ O_3$	·55	3·65
$Zu\ O$	·09	·10
$Ca\ O$	·81	·80
$Mg\ O$	·37	·82
$H_2\ O$	5·82	7·99

These minerals were heated to 95° Cent. for some hours, and the water determined by heating to redness.

No. 3 (SAME LOCALITY).

Layers of amorphous felspar and chalcedony, sometimes containing crystalline quartz. The felspar, apparently when unchanged of a dull greyish brown colour, passes through various shades of blue to a very dark blue, at the same time becoming richer in silica and much harder. The silica appears to increase still more, until the variety is hard enough to scratch glass. In one instance the hard blue variety graduates into almost pure chalcedony of a dull grey colour.

No. 4 (SAME LOCALITY).

A series of layers, each about 2 millimetres of gypsum, soft brown Hepatinerz, black Kupferpechez, and Atacamite, with Calcite.

No. 5 (SAME LOCALITY).

Resembles vari-coloured jasper so much in appearance, that were it not for an unmistakable piece of typical Chrysocolla of the usual hardness thereon, it would probably be taken as such. The colours are blue, blueish green, brown, grey of all shades, from black on one side to white on the other. Dendritic manganese ore is disseminated throughout the entire mass. In some cases there is semi-opalescent quartz mixed with the Chrysocolla.

No doubt can be entertained that this stone represents various stages of deposits of copper and silica in solution, sometimes the one, at other times the other in excess. The solution would also at times have more or less iron or manganese present. The analysis of this hard vitreous variety shows no less than 67 per cent. silica and 5·8 water, so that the surmise by Berthier of opal silica being present is probably correct, as both physical and chemical examinations confirm it.

No. 6, FROM UTAH.

Is composed of both brown and blueish green varieties. The fibrous radiations of malachite pervade the stone, and as some of these are completely converted into Chrysocolla, the stone possesses great interest.

No. 7, FROM PERU.

As typical of a parcel of some 300 tons, this is instructive. It consists of a mixture of Chrysocolla, Malachite, and Atacamite, the latter two being generally

crystallised. As some characteristic crystals of Atacamite are partially converted into Malachite, and this passes into Chrysocolla, it would appear that the above sequence represents the age of these minerals in this locality. I also find crystals with the characteristic form of Malachite converted into a Silicate of Copper.

No. 8, FROM PERU.

Represents another large importation of quite a different characterr It looks as if it had been subjected to decomposing agencies. Numerous cavities occur in which the Chrysocolla is almost crystalline. In some instances layers of small quartz crystals are found, and on these, very minute crystals of Dioptase of a rich emerald green occur.

No. 8, FROM CHILI.

In this stone are nodules of a brown-red variety, encircled by the blue. As the depth of the blue increases as the kernel (other colour) is neared, there seems to be a connection between the two. The red probably existed formerly as Cuprite, or native Copper, and has since been decomposed. This view of the origin of Chrysocolla is maintained by Dr. Burghardt. It is interesting to notice that at one portion of the stone minute Crystals of Dioptase are met with, while in another, quartz Crystals, with native Copper interspersed between them, are found.

No. 9, FROM CORNWALL.

One of the typical specimens from the celebrated Wheal Gorland Mine contains well defined crystals of Olivenite on pseudomorphous layers of quartz. At the base is a mass of Green Chrysocolla passing into Kaolin. It fuses with ease before the blowpipe.

No. 10, FROM CORNWALL.

A piece of ordinary Cornish Granite, from South Carn Brea Mine. It has a small vein of Cuprite, about 2 metres wide running through it. The Felspar crystals on either side have been partly converted into Chrysocolla, and this alteration is greater as the Cuprite is neared. The small quartz crystals seem to be surrounded with layers of Chrysocolla, while the Mica has been quite changed into thin hexagonal flakes of a bright green colour, resembling Chalcophyllite.

No. 11, FROM CORNWALL.

This stone, from South Caradon Mine, shows very clearly how Chrysocolla may be found in the decomposition of other Copper Ores. One portion consists of almost pure Kaolin, but in another part several nodules of Chrysocolla surround inner kernels of Chalcocite. Examining one of these nodules we find the central portion to be quite compact Chalcocite, with the ordinary streak and sectility of that mineral. Proceeding outwards the streak becomes less metallic, and nearly earthy, of a white colour. The mineral assumes gradually a reddish brown colour, as if some small quantity of iron present had been converted into oxide, and then a layer of Chrysocolla is reached. This is first of a deep blue colour, and then shades gradually away to pure white Kaolin. The depth of its blue colour appeared to coincide inversely with the adherency of the stone, as if with the increased per centage of Copper, the Kaolin lost its ordinary property of adhering to the tongue.

An examination of the literature on this ore shows such a variety in the per centage of Copper and Silica, of what are called pure specimens, that I am tempted to

lay down the proposition that no formula can be tabulated for the mineral. In fact, the term "Chrysocolla" should be taken as representing a group of Hydrated Silicates of Copper, varying in chemical composition and behaviour, also in physical character and blowpipe reaction.

Dane ("System of Mineralogy," p. 403) gives the results of 15 analyses of what I presume are pure varieties, as in p. 404 he gives 11 analyses of impure ones. The results of these fifteen show the following per centages :—

	Min.		Max.	
Oxide of Copper.....	28	to	45	per cent.
Silica	26	,,	52	,,
Water.....	16	,,	31	,,

This seems sufficient to show the absurdity of giving a fixed formula for the mineral, but Mr. Hutching's analyses, showing in one case (No. 3) 67 per cent. Silica and 25 per cent. Oxide of Copper, and in the other (No. 5) 47 per cent. Silica, with 39 per cent. Oxide of Copper, and 3·6 per cent. Alumina, demonstrate the absurdity in even a more striking manner. These varieties, so different in all their characters, are, as I have shown, connected together by others of an intermediate character, so that a complete gradation can be established from a variety hard enough to scratch glass to one soft enough to be scratched by the finger nail; from one infusible before the blowpipe to another fusing easily; from an ore containing 25 per cent. Oxide of Copper to one containing 39 per cent. Again, every gradation can be traced from the typical varieties of Chrysocolla through others containing less and less copper, until we arrive at Chalcedony on the one side and pure Kaolin on another.

Some little light, too, is thrown on the probable formation of Chrysocolla by the examination of so many varieties, and I think we shall have to allow of at least more than one mode. In the specimen, No. 11, where a gradual change can be seen in the condition of the Ore acted on, and also in the condition of the Kaolin surrounding, there seems but little doubt of its resulting from the action of these minerals on one another in the presence of water. In specimen No. 5 the mineral appears to have been formed from a solution, in which Copper and Silica were both present, sometimes the one and sometimes the other in excess. Dioptase crystals would seem to be formed when the proportion of Copper and Silica, such as it is composed of, existed.

JANUARY 8TH, 1878.

THE VICE PERSIDENT, WILLIAM SEMMONS, ESQ., in the Chair.

The following communication was read:—

ON THE BEDS IMMEDIATELY OVERLYING THE UPPER PEAT OR SO CALLED FOREST-BED OF THE CHESHIRE SHORE.

BY CHARLES POTTER.

FEBRUARY 12TH, 1878.

THE VICE-PRESIDENT, WILLIAM SEMMONS, ESQ., in the Chair.

The following communications were read: —

NOTES ON THE MINERALOGICAL STRUCTURE OF SOME CORNISH GRANITES.

BY WILLIAM SEMMONS.

THE Granite districts of Cornwall have by some writers been compared to islands which rise out of a sea of clay slate. The three largest patches, which form, as it were, prominent processes in the backbone of the county, also contain the chief veins of metallic ores for which Cornwall has been celebrated so many centuries.

The scanty vegetation of these Granite districts, with their scattered boulders and Logan rocks seems to make a fit home for the giants and piskies which the interesting legends of the people say resided here. Passing, too, from the fertile meadows on the southern shore to the bleak wild moorlands of the Granite districts, we can easily trace the relation between the Geology and Agriculture of a district.

Of late years the commercial value of Cornish Granite has vastly increased, and now many thousand hands are employed in connection with the various Granite works. Chief among these are the fine quarries of the Messrs. Freeman, whose enterprise and skill have caused the various kinds of Cornish Granite to become known. Not only do they furnish large blocks for dock works, &c., but their polishing department shows some of these

Granites to have a highly ornamented character. This process of polishing, while it renders the stone more pleasing to the eye, also enables its structure to be examined more easily, and as, through the liberality of the Messrs. Freeman, I have been enabled to examine no less than eight distinct and characteristic varieties from their various quarries, I have great pleasure in stating the results thereof. The specimens being of large size, I have been able to investigate sections of crystals of the various minerals at every angle, so that the innermost structure could be ascertained.

Before describing in detail the special characteristics of each variety, it may be well to first speak of these Granites in general terms. They may be considered as typical members of their class, being composed generally of orthoclose quartz and mica. Sometimes oligoclase is present. The micas are represented by both the principal groups, Muscovite and Biotite. The quartz is usually white or dull grey, but sometimes is of other tints as red, brown, &c. Many other minerals are found in it, sometimes forming a large portion of the rock. Amongst these are schorl (tourmaline), fluor spar, &c. The description given by Dr. Haughton ("Trans. Royal Irish Academy," vol. xxiii.) of the great Leinster mass of Granite seems fairly to represent those of Cornwall.

The felspar never forms less than one-third, rarely less than one-half, and generally a still larger proportion of the mass. The whole of the four or five minerals seem embedded in a felspathic paste, which does not assume any definite crystalline form, and seems to be the superfluous mineral which remained unused when the other minerals were formed.

Prof. Ramsay ("Physical Geography and Geology of Great Britain," p. 51) says:—"In Granites there is

generally a quantity of free silica, not always crystallised in definite forms like the two other minerals enveloping the crystals of felspar and mica." The Cornish Granites resemble the description of Haughton rather than that of Ramsay.

I now proceed to describe the structure and mineralological characters of the different varieties.

No. 1.—CARNSEW.

May be considered as a Granite of ordinary appearance, having the cold grey colour of Granite hills, as usually seen.

Composed of felspar, quartz, and mica; the quantity of the former being rather in excess of the other two.

Felspar, in imperfectly formed crystals, sometimes $\frac{3}{4}$ in. by $\frac{1}{4}$ in., and enveloping the quartz and mica.

This seems to be the last mineral which consolidated, if the mica is not derived from it. It forms the paste spoken of by Professor Ramsay. The colour is generally white. H = 6.

Quartz occurs in detached crystals, and in long continuations of these crystals. In some cases the crystals are cut across perfectly, and show the section of the hexagonal prism, and occasionally the layers of growth are to be seen. The quartz is of a light purplish grey colour.

The mica is frequently found embedded in the quartz and around the edges of the felspar. Sometimes very small flakes are found along small lines of fissure or cleavage in the felspar, but this only rarely.

The variety is generally that known as Muscovite. It generally occurs in layers of from $\frac{1}{100}$ in. to $\frac{1}{16}$ in. by $\frac{1}{16}$ in. to $\frac{1}{2}$ in. in length.

No other minerals seem present in the rock, and it presents the character of having undergone but little change since its formation.

No. 2. CARN GREY.—CORNWALL.

In this Granite the felspar is much in excess of the other ingredients.

Felspar is of a white colour, sometimes in imperfect crystals 1 in. in greatest length by $\frac{3}{8}$ in. wide. It also forms the ground mass of the rock, and has evidently been formed after the quartz. Colour, white. H = 6.

Quartz.—This mineral occurs in detached crystals, larger than in No. 1, and not in the long continuous lines. In some cases sections of the hexagonal prism are shown with a diameter of $\frac{1}{4}$ in., but they are more often $\frac{1}{16}$ in. The lines of growth are beautifully seen in some instances, and occasionally what appears to be hollows in the quartz crystals. These are probably the cavities investigated by Sorby. The mica occurs in disseminated patches of $\frac{1}{100}$ in. to $\frac{1}{4}$ in. Probably the latter is the width and the former the thickness of the mica deposits. The variety is again Muscovite, mostly of a dark colour, but with an occasional flake of white variety.

As a rule, it is found around the quartz crystals, but in one instance it looks as if a crystal of felspar were being decomposed into a mica. No other instance of change can be seen in the stone.

No. 3.—LAMORNA. CORNWALL.

A porphyritic variety of a greenish yellow colour, when viewed as a whole.

The appearance is rather pleasing, owing to the large crystals of white felspar being well shown up by the considerable quantity of black mica and vari-coloured felspars surrounding them.

Felspar of two varieties.

1st. White variety, resembling albite, occurring in crystals $1\frac{1}{2}$ in. by 1 in. down to $\frac{1}{4}$ in. by $\frac{1}{16}$, frequently containing flakes of mica embedded. This has a hardness of 6 —

2nd. Green and yellow variety in crystals $\frac{1}{4}$ in. by $\frac{1}{16}$ in., and forming the enveloping compound. The quartz is found in small crystals $\frac{1}{16}$ in. to $\frac{1}{10}$ in. Mica usually in very fine flakes, scattered throughout the ground mass, which, in fact, consists of amorphous felspar, and mica. Few of the large felspar crystals are quite free from flakes of mica in them. In one instance, the mica has assumed the shape of a felspar crystal, and also sets off branches into another crystal, as if it resulted from the decomposition of the latter. This crystal is $1\frac{1}{4}$ in. long by $\frac{3}{8}$ in. at shortest width.

One would say this rock shows a somewhat altered appearance to its original structure.

No. 4.—LUXULYAN. CORNWALL.

In this variety the surface to the extent of about one-eighth is occupied by mica, the remaining portion being about equally divided between felspar and quartz. There is also a saponaceous or greasy feeling mineral (a variety of lithomarge), sometimes occurring in distinct spherical nodules, but more frequently occupying the centre of felspar crystals, and occasionally having the perfect shape of the felspar crystals.

The felspar appears in large crystals $1\frac{1}{2}$ in. long, sometimes down to $\frac{1}{2}$ in., but does not appear to form an enveloping paste, as in some other instances. Colour, white. H = 6, and frequently contains small flakes of *mica.*

The quartz occurs in long continuous sinuous lines, showing an appearance similar to the columnar structure noticed in Basalts. In one crystal a pear-shaped cavity is seen about $\frac{1}{20}$ in. long, and in some others, irregular shaped cavities, from $\frac{1}{100}$ in. wide are seen.

The mica is black, in groups of flakes about $\frac{1}{8}$ in. by $\frac{1}{8}$ in., generally surrounding the felspar crystals, occasionally embedded in them. This is probably a rock in which some change has been caused, as when the felspar crystals show signs of change they are softer, and the change to the saponaceous mineral is gradual.

No. 5.—TROWLESWORTHY. DEVON.

In this the quartz occurs in irregular patches of various shapes, sometimes 1 in. by $\frac{1}{4}$ in., at others $\frac{3}{8}$ in. by $\frac{3}{8}$ in. The felspar forms the ground mass, and certainly more than half the bulk.

The quartz preserves the ordinary appearance, and shows some of the cavities noted by Sorby.

There are two varieties of felspar—one of a white colour, which occurs in crystals of varying size, from $\frac{1}{4}$ in. by $\frac{1}{16}$ in. to $\frac{1}{2}$ in. by $\frac{1}{4}$ in.—the other of a red colour, forming the ground mass, and encircling the white variety, also frequently the patches of quartz.

The micas are of the dark variety, also the silvery—probably two varieties of Muscovite.

The quartz crystals are much more perfect than the felspar, and are occasionally seen *protruding through the latter.*

The rock seems to have consolidated under conditions which allowed but little play to the crystalline forces, and to have had a large quantity of iron in it.

No. 6.—WHITE ROCKS. CORNWALL.

A remarkably fine grained Granite, looking as if the mass were made up of minute crystals of orthoclase, quartz, and mica.

The quartz in crystals seldom more than $\frac{1}{20}$ in. diameter. Some of these show cavities, which are generally round.

Felspar appears in an amorphous paste, and also small crystals, of a grey colour; some larger ones are also found confusedly scattered throughout. These vary from $\frac{1}{8}$ in. by $\frac{1}{4}$ in. to $\frac{1}{4}$ in. by $\frac{1}{8}$ in., and are generally white, sometimes tinged with yellow.

Mica is generally scattered throughout the stone in minute specks. Sometimes clusters are found $\frac{3}{16}$ in. by $\frac{1}{4}$ in.; black colour. No other mineral seen.

The consolidation of this Granite seems to have taken place under conditions which allowed less play to the crystallising forces. In one instance the largest felspar crystal on the stone has one end imperfect, owing to the quartz *crystal occupying the space*. The quartz is perfectly formed.

No. 7.—GRANITE FROM NEWLYN.

A highly schorlaceous variety, in which by far the greatest portion is made up of very minute crystals of felspar quartz and chorls, giving rise to an almost black ground mass, whilst scattered through it are crystals of yellowish white felspar, evidently undergoing decomposition.

On examination with a low power the rock is seen to be covered with small hollows, showing decomposition has been at work.

Almost all trace of the original Granite structure is lost, and were it not that it can be traced by degrees into Granite of normal appearance, its origin would be a matter of speculation.

No. 8.—LUXULLIANITE.

This is evidently an altered rock. Essentially large crystals of felspar, with two kinds of tourmaline, and crystals of quartz.

The felspar crystals vary in size from 2 in. by 1½ in. down to $\frac{1}{16}$ in. by $\frac{1}{20}$ in.

The edges of the felspar crystals are jagged, and show it has undergone change. This is confirmed by the general appearance of the specimen, which presents a marked contrast to the firm and compact nature of Granite.

It is considered—and, to me, it seems with very good reason—to be an altered Granitic rock.

This remarkable rock occurs in Boulders only, as the parent rock is unknown. The sarcophagus of the late Duke of Wellington is made from it. It is described very fully by Prof. Bonney in *Mineralogical Magazine*. In this most valuable essay the relation between tourmaline and mica is shown in an altogether new light.

Closely related to the Granites are the Elvans of Cornwall. These two consist largely of felspar: in some cases to the extent of three-fourths of the mass. They also contain, often perfectly formed, crystals of quartz, and occasionally a variety of other minerals. The relations of these dykes to the Granitic masses and overlying clay-slate would constitute material for another paper.

Summarising the facts observed, we find an examina- of the eight varieties before described shows:—

1st. The felspars are usually in excess of the other constituents, and present the following features:

a. They form by far the larger portion of the ground mass.

b. The crystals are sometimes imperfect, from their edges being cut off by those of quartz.

c. The crystals are frequently penetrated by quartz crystals, which latter have their form perfect and not distorted.

d. The crystals and ground mass sometimes show traces of pseudomorphism into tourmaline (schorl) and mica.

2nd. The quartz is usually in well-defined prisms, with, in some cases, perfect pyramidal terminations. A consideration of the foregoing facts leads to the following conclusions or deductions:

A. We find, from a consideration of "*b*" and "*c*," that the quartz was evidently the first mineral to crystallize.

B. Metamorphic action has been at work even in these rocks which appear to retain their original hard structure.

C. This metamorphism seems to be related to the appearance in the rock of schorl (which contains boracic acid and fluorine).

This latter deduction confirms the results spoken of by Bonney, Foster, and Collins. Probably the immense masses of decomposed Granite and Elvan in Cornwall and elsewhere may hereafter be found to have resulted from emanation of gases or percolation of water charged with such gases from below, rather than, as formerly taught, through the influence of waters which have been acidulated at or above the surface of the Earth.

ON THE MICROSCOPIC STRUCTURE OF THE CARBONIFEROUS LIMESTONE WITH REFERENCE TO ITS MODE OF DEPOSITION.

By Henry C. Beasley.

Having lately examined, microscopically, a number of specimens of Carboniferous Limestone, principally from North Wales and Somersetshire, the author brought a few notes of his observations before the Society.

A piece of Limestone free from any large fragments of shells or other fossils, when examined under a 1-inch objective, is usually found to consist of more or less opaque amorphous particles, and fragmentary or perfect fossil Microzoa scattered through a transparent crystalline matrix; but the various proportions of each vary greatly. The Microzoa often are entirely absent. In some cases the opaque particles are so numerous that there is scarcely any of the matrix visible; in others they are very scarce, whilst the fragments of fossils stand out clear and distinct from each other in the transparent matrix.

The most common Microzoa are Foraminifera of the Genera, Trochammina, Endothyra, and Textularia, fragments of the skeletons of Polyzoa, spines of Echini. Occasionally the calcareous bodies found in the skin of many Echinoderms, Sponge spicules, and in some Limestones are bodies supposed to be the tests of radiolarians.

Certain dark coloured Limestones contain fragmentary forms of apparently vegetable origin, and this supposition is confirmed by the fact that a Limestone of this character at the base of rocks forming the Great Ormeshead has been found to contain 3 per cent. of carbon.

Besides the appearance above described, there are many beds in the Carboniferous formation exhibiting öolitic structure. This is not so common in North Wales as in the South of England. Mr. Morton has kindly given me a specimen from Llanymynech which exhibits this structure, and which is remarkable for the large size of the öolites, which lie in a granular matrix, the whole held together by a transparent cement. Mr. G. W. Shrubsole, of Chester, also mentions a bed in the Vale of Clwyd. This structure is, however, very commonly met with in the Carboniferous Limestone in the neighbourhood of Bristol and the Cheddar cliffs in the Mendips.

The öolites are spheroidal bodies more or less opaque, and shew, in section, a number of concentric rings, the latter often crossed by numerous radiating lines. The nucleus consists generally of a fragment of a Foraminifer or a minute crystal, or occasionally a perfect fossil. The space between the öolites is usually filled with a transparent crystalline matrix, but occasionally, as in the specimen from Llanymynech, with minute granules. It is not at all unusual to find a Foraminifer between the oolites, and having no trace of any deposit or aggregation of particles upon it.

The conclusions arrived at with reference to its deposition was that the bulk of the Carboniferous Limestone was the result of the disintegration of coral reefs, by the action of the waves. Sea water is rarely found to contain more than one-fifth of the amount of Carbonate of Lime it is capable of holding in solution ; it, however, acts so slowly on organically formed Carbonate of Lime, of which, of course, coral reefs are composed, that the detritus is carried away in much larger quantities than the sea water can dissolve before it is deposited in deeper water as a calcareous mud, entombing the remains of

the organisms inhabiting the superjacent sea. Comparing a section of Limestone with one of Chalk, the difference in the microzoa is at once apparent. Foraminifera are abundant in each, but the genera differ greatly, the Chalk showing oceanic forms, such as are found in the recent Globigerina ooze, whilst the genera found in the Limestone point to shallower water. Again, the chalk is almost entirely made up of organic remains, whereas the amorphous particles before mentioned form by far the greater part of the Limestone. The deposits now forming in the enclosed seas between Torres Straits and the Straits of Malacca are apparently the modern representatives of the Carboniferous Limestone.

Some beds are undoubtedly the remains of coral reefs *in sitû*, as may be seen from the abundance of reef forming corals they contain. Other beds, and probably all containing vegetable remains, have been formed nearer shore, as well as those Limestones which are mainly composed of the shells of Mollusca; but, as far as the microscope throws a light on the subject, the finer and more massive beds appear to have been formed in moderately deep water of, say 400 to 1,000 fathoms, in the manner mentioned above.

With regard to the oolitic beds, their modern representatives are certain beach sands and sandy patches, or coral reefs, now consolidating with a distinct oolitic structure, as described by Dana, Jukes, and others; but it is hardly probable that all the limestone shewing this structure should have been formed in a similar manner; and the author suggested the possibility of a tendency in very finely comminuted detritus to form spheroidal concretions, so as to form an öolitic rock in deep water.

MARCH 12TH, 1878.

CHARLES RICKETTS, M.D., F.G,S., in the Chair.

HENRY BRAMMALL was elected an Ordinary Member.

The following communications were read—

SOME FURTHER NOTES ON THE SUB-MARINE FOREST AT THE ALT MOUTH.

BY T. MELLARD READE, C.E., F.G.S., F.R.I.B.A.

My attention having of late been more particularly directed to the remains of the submarine forest at the Alt mouth, in consequence of finding a great many mammalian bones—which I purpose describing at some future time—and also by the rapid changes which are taking place, I invited several of our Society to the uprooting of one of the stumps. This I have described in a short paper sent to the London Geological Society.*

I have since inspected the forest, to ascertain in what manner the trees grew and were preserved. The bases of the trees are represented in some cases by stools a couple of feet high, in others only by the ramifications of the roots; while where the peat has actually been skinned off we see nothing but tap roots in groups on the surface of the blue clay. The roots are invariably in a very spongy and decayed condition. In one or two cases the star-like ramification of the roots from the basal stump along the surface of the peat is very prominent, and these again throw out tap roots penetrating the blue clay or sand beneath. I took the positions and distances apart of the trees in a group which I here represent. They varied from 8 yards to 2 yards apart. In another case there was an oak stool with two appa-

* "The Submarine Forest at the Alt Mouth."—Quar. Journal of Geol. Soc., vol. xxxiv., pp. 147–8.

rently smaller trees, represented only by basal roots, 1½ yards from it, measuring from centre to centre. The whole of the group were oaks.

The roots of another stump measured, so far as they extended and were exposed on the surface of the peat, 4 yards across. Our excavation showed that the roots struck diagonally into the blue clay in the two examples we tested, and I have little doubt but that all are pretty much the same as those we tried.

I have also closely examined the constitution of the peat, and I find that the bulk of it is composed of decayed woody fibre and bark, with some grasses and water plants. The silvery bark of the birch is very prominent, and I find it in some cases resting upon the sandy soil of the upper part of the shore which the blue clay graduates into. The lower part of the peat is especially prolific in branches and bark.

From the abundance of forestal remains it is quite clear to me there has been a long succession of growth. The proximity of some of the stumps in various groups also shows that the trees cannot all have grown at the same moment. The fact that the stumps are actually rooted into the ground is positive evidence the trees grew in situ. The difficulty that some of the members of this Society feel in conceiving how the first growth of trees could have rotted before the next set grew is therefore only a difficulty, if it be one, to be explained.

The stumps of the trees are in various stages of decay, as we should expect from a successive, not a simultaneous growth. I think it probable that the situation was at the first a moist one, favourable to the growth of the alder, of which there exist remains. It is quite clear it was never a swamp or bog until the whole forest became finally destroyed. It is also evident that

there existed some antiseptic conditions which allowed the remains to accumulate and be preserved. In many cases the bark of the branches is pressed close together, the internal woody fibre having decayed.

The tree we dug up, portions of which are in my garden, grew after the first layer of vegetable matter had accumulated, for the basal portion of the trunk has a layer of peat about 4 or 5 inches thick, largely composed of bark and branches, adhering to it now, and there is peat under the roots where they commence to branch off from the stool.

When a layer such as this had accumulated, it is easy to see that the deposit would have strong preservative qualities.

The roots of the trees must in all cases have been preserved; had they not been, we should find casts of them in the blue clay. To my mind, the whole question of the growth and decay of these forests never presented any serious difficulties. Now the evidence is certain, complete, and full.

One positive fact is worth a mass of negative evidence, and I cannot help regretting the prevalence of a style of reasoning on facts of Geology which appears to me more like the arguments used by a few singular people who maintain that the world is flat, than the scientific induction we expect from those who investigate Nature with a view of eliciting truth, by methods which any observer, if he takes the trouble, can test for himself. *February 4th, 1878.*

Since writing the preceding notes I have several times visited the site of the forest. The denudation from day to day reveals more clearly the nature of the deposit. Where there formerly only appeared to be peat, the sea, skimming off a layer of it, reveals the

roots of trees branching out on the surface in all their various ramifications; and at other places we see when we come to the broken edge of the peat, the roots striking into the clay below. I have over and over again traced in this way the roots to the parent stem. From day to day I have collected the bones washed out of the deposits, and lately have been fortunate enough to find a number of them in situ. Just south of Thornbeck Pool there is a patch of much denuded peat, revealing the blue silt below in places. In this patchy piece I have found several bones embedded in the surface of the silt or peat. In one case particularly I noticed a small, dark, shining substance peering above the surface; on digging down I found it was the right ramus of a horse, embedded vertically, the hollow of the bone being filled with a sandy matrix. Its position was close to some roots striking through the clay, which I cut through in extracting it.

A microscopic examination of the silty sand inside the bone showed it to be principally composed of grains of quartz, partially rounded, but many angular and broken—in fact, what is known as "sharp sand." I found one or two very minute fragments of shell among it.

Excepting on this patch, I have not found any bones in situ. It appears to me they are mostly derived from the surface layer of silt under the peat, or from the peat itself.

One peculiarity of the bones is the glossy surface they usually present, appearing as if polished.

In one or two cases the bones were covered with a sandy scale, which the microscope showed were grains of quartz, cemented together with iron pyrites. It would appear that the bones in some cases antedate the forest; and, as they are scattered about in a fragmentary manner, have probably been washed into their positions

by streams trickling over the sand. From the levels of the land, it is not improbable that some of the inland water has been ponded up by the tides. The deposits have all an estuarine character.

At the request of the Historic Society of Lancashire and Cheshire, I gave that Society a brief account of the digging up of the oak tree previously alluded to. Judge of my astonishment, when two gentlemen well known in connection with the subject, without in any way calling the accuracy of my description in question, passed over the facts stated as a matter of no moment, and attempted to argue that the trees had not grown in situ because *such was an impossibility*. It has been stated over and over again by the same gentlemen—unless my memory very much betrays me—that the principal evidence against the trees ever having formed part of a forest which existed on the same spot was, that the roots never penetrated the ground below. Having demonstrated to eight gentlemen of various professions and occupations, and possessing considerable scientific attainments, that the trees are rooted in the ground, I certainly thought the matter settled. Mr. Potter and Mr. Boult think otherwise; and, although I consider their objections of no weight against the positive evidence of the rooted trees, it may not be altogether lost time to examine the nature of their difficulties.

1st. "The trees could not be preserved unless embedded in water." 2nd. "Water is absolutely necessary to fossilisation." 3rd. "If there was water the trees could not grow." I have shown the place was a moist one, and that the remains of the birch, alder, and willow underlie the whole of the peat beds. Mr. John Blenkarn, Agricultural Engineer and Surveyor, says in "British Timber Trees":—"The alder is an aquatic and

grows best in boggy ground and a black wet sandy soil, and may be seen sometimes flourishing amid standing water; but it will also grow on a moderately dry soil. The roots appear to have the power of attracting all the moisture and nourishing juices from the earth, rendering it totally barren round the tree." Of the birch he says: "There is hardly a soil so dry, so poor, so wet, so exposed, that this tree will not thrive in: the Earl of Haddington calls it 'an amphibious plant,' and the manner in which it endures removal from one extreme to another appears to justify this remark." The willow, he says, delights in wet and moist situations and the banks of rivers and running water, but may be found occasionally flourishing in higher ground.

Of the Oak:—"There is scarcely any land, however barren, if in some degree elevated, upon which this tree will not grow; stiff clay, hard gravelly soil and black gravelly earth are alike suitable, and fine trees are often seen growing in low and damp situations. The finest quality of oak timber will often be found growing in elevated clay districts."

Of the Pine:—"The various kinds of fir trees will grow well in almost every kind of soil, preferring generally that which is dry and elevated, whether sand, chalk, rock, or gravel."

In a paper on the "Alluvial Strata of the Lower Ouse Valley" (Pro. of the Geo. and Poly. Soc. of the West Riding of Yorkshire), Mr. Franklin Parsons, M.D., F.G.S., says: "There are large woods of Scotch fir in the East Riding growing on the wet heathy surface of the same bed of sand (sand under the peat), and I am of opinion that, therefore, they may be lineal descendants of those which anciently inhabited the district." *

* The accepted opinion is—see Lardner's "Aboretum et Fructicum Britannicum"—that the Scotch pine had died out at the time of the Roman occupation of England.

The Alder, Birch, and Willow are all found in these forest beds, and probably formed the first growth, and this being the case, the conditions for the preservation of succeeding trees would be found. The earliest trees have mostly decayed, and only the roots are found when the peat is skinned off. Of Willows there are portions to be seen, distinguished by the crookedness and branching character of the trunks, but they are very much riven, split up, and decayed, though some sound wood is to be obtained. This applies also to the Alder, of which there is little left, except branches, bark, and roots.

The Oak is the most easily recognised tree in the forest remains. It is remarkable for the soundness of its timber and the straightness of the trunks, appearing as if the trees had grown thickly together—(It is probably *Quercus Sessileflora*)—and the remains of its timber is by far the most abundant. Of the Pine there are examples, and towards the most northern part of the forest the remains of the branches and needle-shaped leaves are most abundant, showing like plumes of feathers spread out on the surface of the peat.

It seems to me rather absurd having to explain to you that it is possible for a thing to have occurred which we know by the best of geological evidence *has* occurred. I will venture to affirm that any other hypothesis than that the trees have grown in the places they now occupy is entirely out of court. If they did not grow on the spot, the alternative is they were washed there by water, or else, what is more absurd, carried there by human agency.

That they could be carried by water and carefully planted so regularly in the ground is a physical impossibility, or, at least, is too great a draught on our credulity to believe. Nor could the vegetable remains have been separated from the alluvial by any known process of

water carrying. If water had transferred them to their present site, we should have had interlaminations of silt and a confused mass of vegetation.

With an apology for this expression of my views, I take leave of the subject.

APPENDIX.

"In the time of the Romans the Danish Isles were covered, as now, with magnificent beech forests. Nowhere in the world does this tree flourish more luxuriantly than in Denmark, and eighteen centuries seem to have done little or nothing towards modifying the character of the forest vegetation. Yet in the antecedent bronze period there were no beech trees, or at most but a few stragglers, the country being then covered with oak. In the age of stone again, the Scotch fir prevailed see p. 9), and already there were human inhabitants in these old pine forest."—Lyell's "Antiquity of Man," page 17.

"According to Rennie, many of these mosses of the north of Europe occupy the place of forests of pine and oak, which have, many of them, disappeared within the historical era." * * * *

"Thus, in Mar Forest, in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, are said to have been soon immured in peat, formed partly out of their perishing leaves and branches, and in part from the growth of other plants. We are also told that the overthrow of a forest by a storm, about the middle of the seventeeth century, gave rise to a peat moss near Lockbroom, in Ross-shire, and that, in less than half a century after the fall of the trees, the inhabitants dug peat there."

"At Tierra del Fuego almost all plants contribute by their decay to the production of peat, even the grasses; but it is a singular fact, says Mr. Darwin, as contrasted with what occurs in Europe, that no kind of moss enters into the composition of the South American peat, which is formed by many plants, but chiefly by that called by Brown, *Astelia Pumila*."—Lyell's "Principles of Geology."

"Abernethy Pine Forest: Some of the trees have attained the age of 200 years; many of them had been thrown down by a great flood of 1829, the stumps of which still remain in soil or sandy moss from 4 in. to 8 in. deep."—Lardner's "Arboretum et Fructicum Britannicum."

"The trees and shrubs known to our Saxon ancestors were the Birch, Alder, Oak, Wild or Scotch Pine, Maiden Ash or Rowan Tree, Juniper, Elder, Sweet Gale, Dog Rose, Heath, St. John's Wort, and the Mistletoe."—*Ibid.*

"Native Birch and Alder are frequently met with in Pine forests, but never are large or valuable."—*Ibid.*

"The Highland Pine in early life grows, although crowded together, to a greater girt; it is found to attain a greater size in very wet ground."—*Ibid.*

"All Oaks when young are remarkable for throwing out long and vigorous tap roots." "The roots of the Oak not being so liable to rot in the ground as those of the Elm, Beech, and other trees, full grown Oaks are not so likely to be blown down by the wind."

The wood of the Alder is homogeneous, tender, and without much tenacity. The bark at the rising of the sap separates from the wood with great facility. It has great durability in water, and Vitruvius recommends it for piles. The wood when worked has the colour of mahogany, but in peat bogs it is black as ebony. The bark of both the Willow and Alder contains a great deal of tannin.

SECTION OF DRIFT-BEDS OBSERVED IN SINKING FOR WATER AT AUGHTON, NEAR ORMSKIRK.

By George H. Morton, F.G.S.

The Author gave the following section of the drift deposits, observed in sinking the shaft at the Springfield Pumping Station, Aughton, near Ormskirk:—

	FT.	IN.		FT.	IN.
Surface Soil	1	0	Sandy Boulder Clay	15	6
Sand	3	0	Gravel	2	0
Sandy Boulder Clay	5	0	Stony Boulder Clay.	5	0
Gravel and Sand ...	15	0	Gravel and Sand...	15	0
Boulder Clay	16	0			
Gravel	1	6		79	0

When Mr. Morton saw the shaft the walls were timbered, but his attention was called to the hard stony character of the "Stony Boulder Clay 5 feet" near the bottom of the section. He was informed that it was very different to any of the higher beds, and on examining a quantity of it that had been brought up, found it remarkably like the "Lower Boulder Clay" described by him in the "Report British Association" for 1876, p. 112.

THE CARBONIFEROUS LIMESTONE

AND

MILLSTONE GRIT OF LLANGOLLEN.

By GEORGE H. MORTON, F.G.S.

(Continued from Page 325.)

CRAIGNANT.

The next section is at Craignant, where there is a fine exposure of the Carboniferous Limestone. The strata belong to the Upper Grey Limestone, and the following is a section of the whole of the beds exposed:—

		FT.	IN.	
Upper Grey Limestone.	Limestone	3	0	
	Shale Limestone Limestone, thin beds	15	0	
	Shale, with beds of Limestone at base..	15	0	Represents the 15-feet of Shale and Limestone at Bron-y-garth.
	Limestone	20	0	
	Shale	0	6	
	Limestone	3	0	
	Shale	0	6	
	Limestone	30	0	Base not exposed.
		87	0	

This section closely resembles that near Chirk, and the occurrence of the 15-feet bed of shale with the same species of shells and corals as at Bron-y-Garth is very remarkable.

The following fossils occur in the 15-feet bed of shale, viz.: *Chonetes Hardrensis; Orthis Michelini; O. resupinata; Productus longispinus; Rhynchonella pleurodon; Spirifera bisulcata; Streptorhynchus crinistria; Poteriocrinus crassus; Chætetes tumidus; Cyathophyllum Murchisoni.*

The general succession of the strata is so similar that it may be considered conclusive evidence that the upper beds of the Upper Grey Limestone were deposited continuously over the intervening country, though they have been denuded and only the lower portion of the subdivision left exposed. The thickness of the Upper Grey Limestone at Craignant, as shown in the section, is about 87 feet, and it is not likely that the actual thickness can be greater, for it includes the whole of the outcrop. It seems that the Silurian rocks on the west of the country described formed land during the deposition of the lowest Carboniferous Limestone, and that it was only after a lengthened subsidence that some of the upper beds were deposited along the old coast line. There is no reason to suppose that the country further west, about Glen Ceiriog, was ever covered by the limestone, though it seems probable enough that the Cefn-y-Fedw Sandstone and Coal Measures may have extended over it.

The succession of the strata from the Carboniferous Limestone up to the Cefn-y-Fedw Sandstone cannot be seen in detail about Craignant. The limestone at the top of the quarry is covered with drift, but probably some

shale comes in, and then the Sandy Limestone, succeeded by the Lower Cefn-y-Fedw Sandstone and Conglomerate, which rises to the south and forms the bold outline of Selattyn Hill.

LLAWNT, NEAR OSWESTRY.

To the south of Craignant the Upper Grey Limestone continues along a band of country usually about one-third of a mile in width. Between the Tumulus and Gorsedd-wen there is a quarry where it has been worked for a long period, and there are several other places where small limekilns indicate spots where limestone has been obtained for agricultural purposes by farmers in the neighbourhood. The limestone is also to be seen along the course of a brook, the Morda, near the same place. About a mile further south the Upper Grey Limestone occurs in a large quarry at Maes-y-graig, and dips 24° to the east. A series of limestone quarries extends along the crest of the ridge trending south, with a steep escarpment to the west; the lower part being formed of Bala-beds on which the limestone unconformably rests. Still further south the Upper Grey Limestone is well exposed resting on similar Silurian strata north of Llawnt, where it is about 108 feet in thickness and presents the following section in the quarries and the ground above them:

		FT.	IN.
Lower beds of the Sandy Limestone.	Calcareous Sandstone?		
	Soft Sandstone, three beds...	3	0
	Dark Red Shale	0	6
	Limestone	10	0
		13	6

		FT.	IN.	
Upper Grey Limestone.	Shale, with bands of Limestone	10	0	Represents the Bron-y-garth and Craignant Shale-beds.
	Concretionary Shale..	10	0	
	Limestone	7	0	
	Shale	2	0	
	Limestone	20	0	
	Shale	1	0	
	Limestone	10	0	
	Shale	3	0	
	Limestone	45	0	
		108	0	

The position, colour, fossils, and general appearance of the limestone and shale in this section and others in the neighbourhood, conclusively prove that the strata belong to the Upper Grey Limestone, which reposes directly on the underlying Silurian strata, and that the average thickness is about 100 feet.

Assuming that the 10-feet bed of shale is on the same horizon as at Bron-y-garth and Craignant, it is the most persistent and remarkable bed in the district. At Llawnt the shale-bed is not so fossiliferous as at the other localities, having a concretionary character, but *Athyris ambigua*, *Rhynchonella pleurodon*, and *Lithostrotion irregulare* occur in it.

The lowest beds of the Sandy Limestone occur in a small quarry a quarter of a mile to the east of Maes-y-graig, at Careg-y-big, as shown in the following section;—

		FT.	IN.
Lower beds of the Sandy Limestone.	Thin beds of sandy limestone, concretionary at the base, with fucoids, or annelid tracks.....	9	0
	Light Grey Shale, with beds of concretionary limestone	3	0
	Limestone, thin beds	3	0
	Limestone with quartz pebbles	6	0
		21	0

Mr. D. C. Davies, F.G.S., of Oswestry, who for many years investigated the so-called Millstone Grit (Cefn-y-Fedw Sandstone) of the district, first described this section and another at Craig Forda, further south, which shows the succession more completely. However, on the hills on both the north and south of the Llawnt-road the line of juncture between the Upper Grey Limestone and the overlying Sandy Limestone may be easily traced.

The Lower Cefn-y-Fedw Sandstone and Conglomerate forms the commanding eminence, Selattyn Hill, the summit being about 1,000 feet above the Ordnance datum, and 250 feet above the village of the same name. There are no quarries on the hill, but the surface about the summit, where not reclaimed, is scattered over with blocks of white sandstone, containing numerous quartz pebbles, and presents exactly the same appearance as at Cefn-y-Fedw, the general aspect of the hill-top being very similar to the typical area of the formation on the north-west of Llangollen. There is a monument on the top of the hill in

commemoration of a battle between the English and Welsh, while the Tumulus close by, and Offa's Dyke, which runs along the strike of the Upper Grey Limestone, all mark the locality as a long-contested battle-field. Rather more than half-a-mile to the north-west of the village, on the hill beyond the brook, there is a quarry in the Cherty Shale, which dips about 20° to the south-east and is fifty feet thick—that thickness being actually exposed. The rock has much the same appearance as on Cefn-y-Fedw, but no fossils were observed. There is another exposure a little to the north-west, where beds of weathered sandstone appear, evidently below the Cherty Shale.

About two miles further south the Cefn-y-Fedw Sandstone is represented about Oswestry race-course, in the picturesque defile or valley of the River Morda, and is also exposed in several quarries in close proximity. The exposures of the Sandy Limestone at Careg-y-big and on the hill above the limestone quarries at Llawnt, have been shown in the sections at pages 373–5, and above those sections the Lower Sandstone and Conglomerate presents a rocky ridge, or is indicated by numerous large fragments of the sandstone containing pebbles of white quartz. The thickness of the Sandy Limestone in this locality is probably about 75 feet, and is certainly represented by the calcareous sandstone and limestone which occur between the ~~top of the~~ Lower Sandstone and Conglomerate and the Upper Grey Limestone at Craig Forda. The latter can be seen exposed at the Forest quarry on the ridge between Offa's Dyke and the race-course, half-a-mile north of the Llawnt and Oswestry-road. The strata present the usual characters: hard white sandstone with white pebbles, 12 feet thick, succeeded by the

same thickness of similar sandstone without pebbles. The beds dip 22° E.S.E. At Cwm-sych, close to the south end of the race-course there are two quarries, in higher strata, where the following section is visible, particularly in the one near Offa's Dyke, where the thickness was measured:—

		FT.	IN.
Lower beds of the Cherty Shales.	White cherty sandstone	12	0
Upper beds of the Lower Cefn-y-Fedw Sandstone.	White sandstone, with the upper beds weathered to a brownish colour	20	0

Below the strata exposed in this quarry much lower beds of the Lower Sandstone and Conglomerate crop out in the defile of the Morda, below Craig Forda, along the eastern side of which they present a ridge extending nearly its entire length of two miles. The depth of the defile is above 300 feet, the rocky ridge being 250 feet above the river, and the strata dip 20° E.S.E. The strata, both above and below the ridge, are hidden by a talus of débris, and a thick covering of soil supporting a plantation, so that the lower beds and the underlying limestone cannot be seen. The beds above those cropping out are evidently composed of hard white sandstone, with occasional quartz pebbles, as fragments of it are numerous on the surface, and the walls of the fields above are built of stone taken from a series of holes along Offa's Dyke, which presents a conspicuous embankment of earth and stones along the top of the defile. The sandstone cropping out in the ridge is usually very

hard, and probably was originally white, but long exposure and weathering at the sides of the ravine have produced a mottled red shade, and in one spot it has been reduced to sand, which contains quartz pebbles. There is a small quarry in the ridge about 50 feet below Offa's Dyke, and exactly opposite Bron-y-Gell, where the thickness of sandstone exposed is about 20 feet, and the dip east-south-east.

The thickness of the Lower Sandstone and Conglomerate seems to be about 220 feet, including the 20 feet exposed in the quarry at Cwm-sych, of which a section has been given, and in Allinson's quarry, about 200 yards to the north. In the latter fossils are abundant in the upper beds, and also occur in the overlying Cherty Shale, which are there composed of regular beds of Chert and very fine grained white sandstone.

Along the greater portion of the Morda defile the direction is coincident with the strike of the strata, but south of Candy it gradually winds round towards the east—crossing the strike and exposing a fine section of the Sandy Limestone, as follows:—

		FT.	IN.
Sandy Limestone.	Calcareous Sandstone	20	0
	Soft Brown Sandstone	4	0
	Limestone, with shales at the base	7	0
	Sandstone, with weathered cavities	1	9
	Dark Red Shale	0	6
	Dark Grey Limestone	18	0
		51	3

The 20-feet of calcareous sandstone crops out *below* the inferior beds in the section, half-way up the side of the ravine, having been dropped by a fault or recent landslip, and that explanation is confirmed by the limestone strata cropping out again below the sandstone just above the Morda.

The strata at the base of the Lower Sandstone and Conglomerate, which must come in over this section, cannot be seen, though there can be little doubt that they are composed of soft red sandstone, for there are indications of such a rock in the débris overlying the outcrop. The upper beds of the Carboniferous Limestone crop out a few yards below the calcareous sandstone in the section, but there must be some beds at both the top and bottom of the section, which would probably increase the thickness of the Sandy Limestone to about 75 feet.

The Cefn-y-Fedw Sandstone is again exposed on the east of the race-course on the north side of the road to Oswestry, in a quarry near Underhill, where the rock has much the same appearance as at Cwm-sych, and the cherty rock is worked for road-stone, the large quantity of broken-up material affording great facilities for examination. It is a very fine grained cherty sandstone, but does not seem to contain any fossils—at least, I was not able to find even a trace of any. Only about 6 feet of the Cherty Shale and 4 feet of the underlying Lower Sandstone are visible, and dip at an angle of 10° S.E.S. Half-a-mile to the east there is another quarry, near a farm house, where there is a hard white sandstone with yellow spots, and a bed of soft shale over it. The beds dip 20° S.E.S., and probably underlie the Cherty Shale at Underhill, but

the surface is so covered with drift that no regular succession can be seen. Although the Sandy Limestone and the Lower Cefn-y-Fedw Sandstone and Conglomerate are clearly represented in the country west of Oswestry, no exposure of the Upper Cefn-y-Fedw Sandstone has been noticed, for the country as it descends to the east is all under cultivation. Probably the underlying sandstone is of a soft character and has been so denuded and covered with drift, that it seldom appears at the surface, and the succession clearly exposed to the north-east of Llangollen is not to be seen.

Besides the fossils that occur in the quarries that have been described, stones of various sizes are thrown off the fields about Cyrn-y-Bwch which contain numerous species, and judging from the lithological character of the rock, have been derived from strata about the top of the Lower Sandstone. Mr. D. C. Davies, F.G.S., was the first to describe the fossils at Cyrn-y-Bwch, and it would seem to be the most northerly locality, except Selattyn Hill, where he has discovered them in the Oswestry district. The most frequent species that occur at Cyrn-y-Bwch are: *Athyris ambigua; Productus longispinus; P. semireticulatus; Rhynchonella pleurodon; Spirifera bisulcata;* and *Streptorhynchus crinistria,* all species that occur in Allinson's quarry.

The Cefn-y-Fedw Sandstone is continued to the south of Craig Forda, when it again rises and forms the commanding elevation of Mynydd Myfyr. All the upper portion of the hill is the Lower Sandstone and Conglomerate, and there are many exposures where it can be seen presenting its usual characters. The Cherty Shale and higher strata in the formation cannot be seen, the country on the east of Mynydd Myfyr being all under cultivation; but there is a bed of coal, to which no

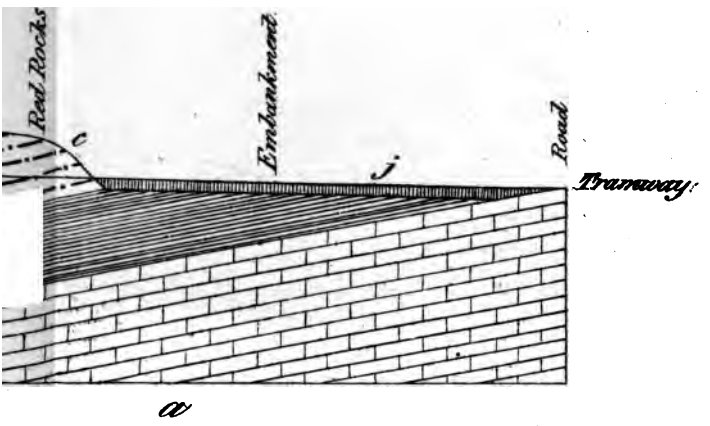
name has been given, represented as in the Cefn-y-Fedw Sandstone according to the Geol. Survey map, though it probably represents the Aqueduct Coal at the base of the Coal-measures. This coal was worked about forty years ago, and the line of outcrop is indicated by the débris that was thrown out of the shallow pits. The thickness of the seam is reported to be about 18 inches, but little is actually known respecting it. The upper beds of the Cefn-y-Fedw Sandstone do not occur at Mynydd Myfyr, and it is probable that the seam is the Aqueduct Coal faulted against the Lower Cefn-y-Fedw Sandstone, all the country to the east being Coal-measures. On the Geol. Survey Map the outcrop is continued to the east of Craig Forda and the race-course, though thrown off its continuity a quarter of a mile by a fault which crosses it, and represented as terminating a little north of Underhill, near the quarry in the Cherty Shale already described. However, I have not succeeded in obtaining any confirmation of its occurrence north of Mynyd Myfyr, even from persons who have long resided in the neighbourhood.

TREFONEN.

The Cefn-y-Fedw Sandstone and the underlying Carboniferous Limestone are broken up by a succession of east and west faults, which, excepting the one just north of Mynydd Myfyr, are upthrows on the south side; and in consequence of the easterly dip of the strata, cause both formations to crop out further to the east with each succeeding dislocation. These faults are shown on the Geol. Survey Map, and explain how the Cefn-y-Fedw Sandstone has been continued so far to the east between Oswestry and Llanymynech.

About Craig Forda and Mynydd Myfyr the Lower Cefn-y-Fedw Sandstone and Conglomerate presents a remarkable change in aspect and colour, and becomes for the most part a soft red sandstone with a conspicuous outcrop, overlaid by a hard white sandstone which retains its original characters. The lower red beds are well exposed 200 yards east of the Upper Grey Limestone quarries at Treflach wood, about half-a-mile south-east of the village of Trefonen, at the spot marked + 10° on the Geol. Survey Map; along the road south-west from Treflach Hall and Bellam Farm—though coloured Carboniferous Limestone on the map; and near the south end of the old tramway constructed some years ago in connection with coal-pits near Trefonen, where the lowest beds form a conglomerate. In all these places the Hard White Sandstone may be seen over-lying the Soft Red Sandstone, though the change in colour seems gradual, and there are some soft yellow beds about the horizon where they blend into each other. The section exposed along the tramway presents nearly the whole of the Cefn-y-Fedw Sandstone, and affords the means of comparing the subdivisions of the formation with those of the typical area. Although the lower beds are obscured by a thick covering of drift they can be seen close to the section, which is of great interest, and was first described by Mr. D. C. Davies, F.G.S., in the "Geological Magazine" for 1870, where there is a wood-cut and description of it. Plate 6 is representative of the strata exposed in the tramway, drawn to scale, showing the top of the Carboniferous Limestone, the embankment and drift which cover some of the lower beds, and the subdivisions into which the Cefn-y-Fedw Sandstone is divided, as follows:—

PLATE 6.



HALL.

SUBDIVISIONS OF THE CEFN-Y-FEDW SANDSTONE AT SWEENEY MOUNTAIN.

		FEET.
Middle Cefn-y-Fedw Sandstone.	Sweeney Mountain Sandstone	100
Cherty Shale.	Pink Sandstone and Shale.....	25
	Summer-house Sandstone	60
	Red Sandstone and Shale	25
Lower Cefn-y-Fedw Sandstone and Conglomerate	Hard White Sandstone	70
	Soft Red Sandstone.....	150
Sandy Limestone.	Sandy Limestone not exposed	75?
		505

The section, Plate 6, runs nearly north and south, and is 1,000 yards in length, the north end being 65 feet higher than the south. The actual dip at the south end is 10° N.N.E., increasing to 16° N.E. about the middle, and finally decreasing to 10° N.E. The thickness of the subdivisions and of the whole has been determined from the above data, combined with observations on the other exposures close by.

The Pink Sandstone and Shale, *g*, is only partially exposed along the tramway, but a parallel fault on the east brings it down in the quarry 100 yards off, where the fossils in the list were obtained. The rounded hillock at the north end of the section is composed of the Sweeney Mountain Sandstone, *h*, a very white and soft rock; but the hill on the east, upon which the summer-house of Stanley Leighton, Esq., M.P. stands, is formed of the Summer-house Sandstone, *f*, resting on the Red

Sandstone and Shale, *e*, the Pink Sandstone and Shale, *g*, having been denuded. The Hard White Sandstone, *d*, is exposed in the section, but little is seen of the underlying Soft Red Sandstone, *c*, though it is conspicuously prominent over a large area on the south of Treflach Hall. The base of the Soft Red Sandstone is not visible, neither can any of the strata between it and the Carboniferous Limestone be seen where the upper beds of the latter dip into the hollow underneath the embankment.

Although there is a considerable lithological difference between the Cefn-y-Fedw Sandstone near Llangollen and the same formation at Treflach Hall and Sweeney Mountain, there are several points of resemblance which assist in correlating the strata of the two areas. There are no strata about Sweeney Mountain resembling the Aqueduct Grit, and there are no black shales and yellow sandstones likely to be on the same horizon as the Upper Cefn-y-Fedw Sandstone. The Sweeney Mountain Sandstone is very similar, but much softer than the Middle Sandstone of the typical area, and though it is succeeded at Gron-wen and Nant by a few feet of yellow sandstone and white shales, it does not seem that the highest beds occur in the district, having probably been thrown down by a fault bringing in the Coal Measures in the direction of Oswestry. There are no beds resembling the Cherty Shale, which occur as far south as Craig Forda, but they are probably represented by the shale interstratified with the Pink, Summer-house, and Red Sandstones of the old tramway section, all of which contain similar fossils. The Lower Cefn-y-Fedw Sandstone around Treflach presents, as already described, a peculiar lithological aspect in its lower beds, which so much resemble the soft sandstones of the Trias as to have attracted the

attention of geologists many years ago,* though the upper beds of hard white sandstone with occasional quartz pebbles continue to characterise the subdivision. In the tramway section there is a space between the Carboniferous Limestone and the red beds of the Lower Cefn-y-Fedw Sandstone where the strata cannot be seen under the embankment. The Sandy Limestone is supposed to occur there, but it is merely conjectural, the nearest sections where such transitional beds occur being at Careg-y-big, Craig Forda, and north-east of Little Nuttree Bank.

The following list of fossils has been compiled from the papers by Mr. D. C. Davies, F.G.S., and Mr. F. C. Prosser, F.G.S., already referred to, only one additional species, *Productus longispinus*, having been added. In several localities described by them I have not succeeded in finding any, as in the Soft Red Sandstone in the tramway section, but Mr. Davies explained to me how the lower beds have been gradually covered by débris during the last seven years. Generally, however, I have found sufficient to confirm the fossiliferous localities, while the Pink Sandstone quarry close to the tramway, Allinson's quarry, and other places about Oswestry race-course, have afforded fully half the species in the list. The localities have enabled me to tabulate the species found in the subdivisions here adopted. They are all ordinary Carboniferous species; nearly all found in the underlying Upper Grey Limestone, just as might be expected considering that further north, at Minera, the Lower Cefn-y-Fedw Sandstone becomes a regular limestone with the conglomerate beds cropping out beneath, apparently forming the upper portion of the Carboniferous Limestone, and is so coloured in the Geol. Survey Map:—

* "The Silurian System." (By Sir R. I. Murchison, F.R.S.)

LIST OF THE FOSSILS FOUND IN THE CEFN-Y-FEDW SANDSTONE, NEAR OSWESTRY.

	SPECIES.	SUB-DIVISION.	LOCALITY.
	CEPHALOPODA.		
1	*Orthoceras giganteum*,* Sow.	Summer-house Sandstone.....	About 220 yards east of the Treflach Tramway, Field No. 2,574 in Parish Map, S.W. corner.
	HETEROPODA.		
2	*Bellerophon*, sp.....	Hard White Sandstone.....	Oswestry Race-course.
	GASTEROPODA.		
3	*Metapoma*, sp.....	Soft Red Sandstone	Treflach Hall and Tramway.
4	*Pleurotoma decipiens ?*	Do.‡	Sweeney.†
5	*Edmondia sulcata*, Phil.....	Do.‡	Do.
6	*Pecten*, sp.	Do.‡	Do.
7	*Sanguinolites variabilis*, M'Coy	Do.	Treflach Hall and Tramway.
8	*Schizodus*, sp.....	Red Sandstone and Shale.....	Treflach Tramway.
	BRACHIOPODA.		
9	*Athyris ambigua*, Sow.....	Hard White Sandstone.....	Oswestry Race-course & Selattyn Tower.

	SPECIES	SUB-DIVISION.	LOCALITY.
10	*Chonetes*, sp.	Soft Red Sandstone	Treflach Tramway.
11	*Lingula mytiloides*, Sow.	Do. ‡	Sweeney.
12	*Orthis resupinata*, Mart.	Hard White Sandstone	Llanforda-isaf.
13	*Productus concinus*, Sow.	Soft Red Sandstone ‡	Treflach Tramway.
14	,, *cora*, D'Orb.	Do.	Do.
15	,, *costatus*, Sow.	Cherty Shale	Allinson's Quarry.
16	,, *longispinus*, Sow.	Hard White Sandstone	Do.
17	,, *semireticulatus*, Mart.	Pink Sandstone Summer-house Sandstone Hard White Sandstone Soft Red Sandstone	Treflach Tramway, Allinson's Quarry, &c.
18	,, *punctatus*, Mart.	Cherty Shale.	Do.
19	,, *Youngianus*, Dav.	Do.	Do.
20	*Spirifera bisulcata*, Sow.	Hard White Sandstone	Do.
21	,, *striata*, Mart.	Do.	Oswestry Race-course.
22	*Streptorhynchus crinistria*, Phil.	Do.	Do.

	SPECIES.	SUB-DIVISION.	LOCALITY.
23	*Rhynchonella pleurodon*, Phil.....	Soft Red Sandstone.....	Sweeney.
	CRUSTACEA.		
24	*Phillipsia*, sp.....	Hard White Limestone.....	Sweeney & Oswestry Race-course.
	ECHINODERMATA.		
25	Encrinital stems undetermined.....	{Red Sandstone..... Hard White Sandstone.....}	Sweeney & Oswestry Race-course.
	ZOOPHYTA.		
26	*Cyathophyllum Murchisoni*, M. Edw.....	Hard White Sandstone.....	Sweeney & Oswestry Race-course.
27	*Clisiophyllum*	Do.	Oswestry Race-course.
28	*Petraia ?*	Do.	Llanforda-isaf.
	PLANTÆ.		
29	*Calamites*.....	Pink Sandstone.....	Treflach Tramway.
30	*Sigillaria*.....	Do.	Sweeney.

* The only specimen found is now in the Liverpool Derby Museum, and it is fully described in the "Proceedings of the Literary and Philosophical Society of Liverpool" for 1875–6; the following paragraph being an extract:—

"This specimen is now three feet eleven inches long, the width at the summit three and a half inches, and at the base fourteen inches; the apical angle being about twelve degrees. It measures only twelve inches in diameter perpendicular to the line of the original bedding, probably from pressure. There are the casts of twenty chambers above what seems to have been the cavity which contained a portion of the animal, and this final chamber is eighteen inches in length. Originally there must have been, at the least, thirty chambers, and the entire length of the shell was probably nearly six feet, so that it is an exceptionally large specimen."

† Sweeney as a locality probably includes the Treflach Tramway and other places around Sweeney Mountain.

‡ Some of these species may have been found in the Hard White Sandstone.

The Cefn-y-Fedw Sandstone is represented on the Geol. Survey Map as occurring over an area of two square miles about Llync-lys, Moreton, and Crickheath Hall. The surface is entirely covered with a thick deposit of drift, consisting of a coarse gravel of pebbles and sandy clay. There is no opening showing the rock, and the wells at the various farms are not supposed to reach it, so that it is difficult to surmise the data upon which the formation below the drift was determined. Mr. D. C. Davies refers to the strata of this area, and seems to consider them to be Permian, and states that they rest upon the Carboniferous Limestone, but without giving any description or any section where they may be seen.* Not having seen any exposure of the strata, no opinion can be here given respecting them. There are some red beds exposed on the west of the road between Lync-lys and Sweeney Old Hall, which might be mistaken for Permian; but they are the Soft Red Sandstone of the Lower Cefn-y-Fedw Sandstone. They are coloured as Carboniferous Limestone on the Survey Map, and may have no relation to the strata below the drift on the east, around Moreton.

UPPER GREY LIMESTONE.

Proceeding southwards from Llawnt, the Upper Grey Limestone forms the gradually ascending ridge of Craig-y-rhiw, where the rock has been quarried in several places, and presents a precipitous scar, with the underlying Bala-beds of the Silurian exposed at intervals beneath. The limestone exposed along the ridge belongs to the lower portion of the subdivision, and is on the same horizon as the lower beds at Llawnt. The scar is

* "On the Coal Seams in the Permian at Ifton, Shropshire."—Proc. Geol. Assoc., Vol. iii., p. 188.

most precipitous at the highest part of the ridge, where the limestone is about 70 feet thick, having broken down in large masses, and a scene of ruinous grandeur produced. The limestone rests unconformably on the Bala-beds, and there is a fine exposure of the latter on the hill side close to the broken masses of rock. A walk along the road from Llawnt to Llansilin affords a good view of the ridge of Upper Grey Limestone; the underlying Bala-beds; the great heaps of limestone that have fallen down the side of the hill, and a deep cutting in the drift, exposed by the flow of the stream in the valley below. At Craig-y-rhiw some of the lower beds of the limestone become very compact, like marble, a condition still more remarkable further south.

At Coed-y-Gaer the Bala-beds rise to the west and to the height of the Upper Grey Limestone, but the lower beds of the latter are exposed by an old limekiln close to Llynrhyddwyn, and are of a reddish colour. Further south, near Pant-hir, there is a quarry where about 27 feet of the same subdivision are exposed. The beds are very near the base of the limestone, the lower half being of a compact structure. Near Pentre-cefn, on the road side, there is another quarry in the same subdivision where the strata are very similar to those at Pant-hir, the following beds being exposed:—

		FEET.
Lower beds of the Upper Grey Limestone.	Light Grey Limestone	5
	Shale	1
	Compact Light Grey Limestone	10
		16

These beds are about the lowest in the subdivision, and are on the same horizon as those at Pant-hir and

Llynrhyddwyn. Higher strata occur at New Inn, a quarter of a mile along the road, in a large quarry, where the following section is exposed:—

		FEET.
Middle beds of the Upper Grey Limestone.	Light Grey Limestone, in thin beds..	30
	Black Shale and Rubble	3
	Dark Grey Limestone, in thin beds...	40
		73

The limestone in this section is all of a grey colour, and evidently on the same horizon as the beds below the thick-shale at Llawnt. There is no exposure of any higher beds of the subdivision in the locality, though they must occur further east.

About a mile due south of Pentre-cefn there is a conspicuous hillock, Craig Sychdin, where the Upper Grey Limestone is worked in a quarry near Wern-ddu, and the following section occurs:—

		FEET.
Middle and Lower beds of the Upper Grey Limestone.	Grey Limestone, with rubble at base.	21
	Shale	1
	Limestone, thin beds—some compact	30
	Grey compact Limestone.....	4
	,, ,, ,, ...	4
	Black Limestone, thin beds.....	8
	Limestone—reddish colour	10
	Limestone, thin reddish beds	8
		76

The strata shown in this section belong to the middle and lowest portion of the subdivision and are of the usual grey colour, but with a reddish shade towards the base. Although the underlying Bala-beds are not actually seen, as in some of the sections previously described, they probably occur just outside, to the west of the quarry. It is seldom that the very lowest beds of

limestone can be seen in a quarry, for they are usually sandy or useless from other causes, and consequently left untouched. The highest beds of the Upper Grey Limestone are not exposed in the locality, and a considerable fault running east-north-east from Craig Sychdin brings up the Bala-beds, throwing the limestone considerably to the east. At Craig Sychdin a lower subdivision of the Carboniferous Limestone—the Upper White Limestone—first presents its appearance, and crops out from under the Upper Grey Limestone, proving that an earlier series of strata was deposited at the southern extremity of the Carboniferous area, as I have previously shown to have been deposited in the country to the north of Llangollen. This lower subdivision rises into three conspicuous hills, is extensively quarried in many places, and is the most important economically considered.

There are several large quarries about Treflach Wood, which is about a mile to the south of Trefonen, where the Upper Grey Limestone again occurs, cropping out from under the soft red beds of the Lower Cefn-y-Fedw Sandstone, the Sandy Limestone not being exposed. The following is a section of the strata forming the subdivision as exposed near the middle of the area in quarries on the east side of the road, which runs north and south, where the beds dip 15° east.

		FEET.
Upper beds of the Upper Grey Limestone.	Shale, base only seen	1
	Light Grey Limestone, two beds	8
	Shale	4
	Light Grey Limestone	4
	Shale	1
	Light Grey Limestone	10
	Shale and rubble, which graduate into the beds below, many fossils.	7
	Dark Grey Limestone, thin beds, with thicker below	18
		48

The thickness of the shale at the top of the section is uncertain, as it is partly denuded and covered by drift. The 7-feet bed of shale and rubble graduates into the beds of limestone below, but is on the same horizon as the persistent and similar bed referred to so frequently before, and it is remarkable about Treflach Wood for the abundant corals and other fossils it contains. About half-a-mile further south there are other quarries in the Upper Grey Limestone, where the beds dip 16° N.W., and present a ridge bounded on the south side of the fault shown on the Geol. Survey Map. This fault is the same as the one which will be described as occurring on the south of the Nant Mawr quarries and running east and west, and is supposed to be continued towards Sweeney Old Hall, where there is some complicated ground caused by faults. Close to the stream and fault shewn on the Geol. Survey Map, the Soft Red Sandstone at the base of the Lower Cefn-y-Fedw Sandstone crops up from under the Sandy Limestone, both being well exposed along the stream. The fault is susposed to have cut off both subdivisions across the strike of the strata.

The following is a list of the fossils collected in the quarries in Treflach Wood, but principally in those at the southern part of the area, one-third of a mile north of the word Camp.

LIST OF FOSSILS FOUND IN THE UPPER GREY LIMESTONE AT TREFLACH WOOD.

1 *Orthoceras giganteum*, Sow.*
2 *Euomphalus*, sp.
3 *Loxonema*, sp.
4 *Athyris Royssii*, Léveillé.
5 *Orthis resupinata*, Mart.
6 *Productus cora*, D'Orb.
7 ,, *costatus*, Sow.
8 ,, *giganteus*, Mart.
9 ,, *longispinus*, Sow.
10 *Spirifera bisulcata*, Sow.
11 ,, *glabra*, Mart.
12 *Alveolites septosa*, Flem.
13 *Clisiophyllum coniseptum*, M'Coy.
14 ,, *turbinatum*, M'Coy.
15 *Cyathophyllum Murchisoni*, M. Edw.
16 *Lithostrotion irregulare*. M'Coy.
17 ,, *junceum*, Flem.
18 ,, *Martini*, M. Edw.
19 ,, *M'Coyanum*, M. Edw.
20 ,, *Portlocki*, M. Edw.
21 *Lonsdaleia floriformis*, Flem.
22 *Syringopora geniculata*, Phil.
23 *Zaphrentis cylindrica*, Scouler.

The highest beds of the Upper Grey Limestone, dipping 16° N., can be seen at the south end of the old tramway near Treflach Hall; and at Dolgoch, east of

* In the Powys Land Museum, Welshpool.

Nuttree Bank, on the north of the road leading to Llync-lys station, there is a large quarry where the strata dip slightly to the north, and the upper half of the subdivision is exposed as shown in the following section:—

		FT.	IN.
Upper beds of the Upper Grey Limestone.	Light Grey Limestone	4	6
	Dark Grey Limestone, six equal beds	7	0
	Black Shale, with many fossils ...	2	0
	Light Grey Limestone.....	5	0
	Black Shale	2	0
	Light Grey Limestone.....	4	6
	Shale	2	0
	Light Grey Limestone.....	9	0
	Black Rubble and Shale.....	3	6
	Dark Grey Limestone, seven equal beds	10	0
		49	6

This section differs considerably from those already described, as it presents more limestone and less shale. However, the 3-feet 6-in. bed of rubble and shale seems to be on the horizon of the persistent shale-bed, and it contains corals, particularly great branching masses of *Lithostrotion*. The regular bedded limestone at the bottom of the section is used for similar purposes there and at Treflach Wood quarries, where it occurs beneath the shale-bed; and the thick bed of limestone above the shale is very much alike at both places.

The following is a list of the fossils collected in Dolgoch quarry, principally in the 2-feet bed of shale towards the

top of the section, which may represent the thick shale, though the 3-feet 6-in. bed near the bottom more closely resembles it, both lithologically and in position.

LIST OF FOSSILS FOUND IN THE UPPER GREY LIMESTONE AT DOLGOCH.

1 *Euomphalus Dionysii*, Goldf.
2 *Athyris Royssii*, Léveillé.
3 *Chonetes Hardrensis*, Phil.
4 *Orthis Michelina*, Koninck.
5 *Productus giganteus*, Mart.
6 ,, *latissimus*, Sow.
7 ,, *longispinus*, Sow.
8 *Rhynchonella pleurodon*, Phil.
9 *Spirifera cristata*, Schloth.
10 ,, *bisulcata*, Sow.
11 ,, *lineata*, Mart.
12 *Alveolites septosa*, Flem.
13 *Syringopora geniculata*, Phil.
14 *Streptorhynchus crinistria*, Phil.
15 *Lithostrotion irregulare*, M'Coy.
16 ,, *junceum*, Flem.
17 *Lonsdaleia floriformis*, Flem.
18 *Zaphrentis cylindrica*, Scouler.

Between Craig Sychdin and Dolgoch little is known respecting the lowest beds of the Upper Grey Limestone, but south of the latter quarry and the Llync-lys road, there is a deep quarry on the opposite hill-side, known as Jones' Quarry, where the lower beds are well exposed as follows;—

		FEET.
Middle and Lower beds of the Upper Grey Limestone.	Rubble and Shale	4
	Light Grey Limestone	10
	Rubble	9
	Light Grey Limestone, two equal beds	2
	Shale	7
	Rubble	7
	Light Grey Limestone	8
	Dark Grey Limestone, thin beds	10
	,, ,, Limestone, three beds	10
	Rubble and Shale	4
		71

The colour of the limestone in the section is of the usual grey shade, and the beds of shale are black or a dark grey. The strata dip rapidly 30° N., and appear to run under the beds at Nuttree Bank and Dolgoch quarry, without any fault between. The upper beds in the section may be observed on descending the hill as they dip towards the road, and the rapid changes that take place within the distance of one hundred yards is remarkable. There are some of the usual fossils to be found, but they are not numerous.

There is an important fault, running north and south, exposed in the middle of Jones' quarry, which throws up some of the highest strata of the Upper White Limestone to the surface on the west side of the quarry—beds that lie beneath the Upper Grey Limestone on the east side. This fault is more fully described and a woodcut given of it, Fig. 10, page 403, under the head of Porth-y-waen. There is no trace of the Upper Grey Limestone further south, and though it must have extended over the Upper White Limestone some miles in that direction, all trace of it has been removed by denudation.

Reference has already been made to the Upper White Limestone which underlies the Upper Grey Limestone, and crops out in thick beds at Nant Mawr and other places to the southwards. In general appearance it differs considerably from the Upper White Limestone at Eglwyseg ridge, for the interstratified thick shales are limited to its upper beds, and it does not appear in such conspicuous natural sections as in the typical district. Lithologically the limestone is very similar, being of a compact structure, and often like marble, especially the beds about the middle of the subdivision. The shale that alternates with the upper beds is usually of a reddish shade, so that the water that trickles down the sides of the quarries gives a red appearance to the limestone, which, when it is broken, is found to be generally of a light grey, though sometimes it assumes a drab, yellow, or brown colour. Being on the horizon of the Upper White Limestone near Llangollen, under the Upper Grey Limestone, it is assumed to represent the former subdivision—its thickness at Nant Mawr and Porth-y-waen not being sufficient to include the Lower White Limestone, which is only represented along the base of the Llanymynech Hill by a series of beds of red shale and limestone, resembling the 5-feet of shale above the *thick-bed* at Llangollen. The fossils in the subdivisions do not much aid in identifying them, for although there are some peculiar species found in the 30-feet bed at the top of Llanymynech Hill, others are common to both the Upper Grey and the Upper White Limestone. The distinctive characters that serve to identify and to separate the two subdivisions are purely lithological, the Upper Grey Limestone being composed of grey and black limestone, and shale exactly similar to the same beds in the Eglwyseg ridge; while

the Upper White Limestone is usually of a light grey or cream colour, the beds being interstratified with red and purple shales, so that it is usually easy at a glance to determine the subdivision to which the strata belong, especially where the rock is quarried and well exposed. The difference between the two subdivisions was shown to be remarkable in the Eglwyseg ridge, and it is equally clear and distinct over the Llanymynech area.

NANT MAWR.

At Nant Mawr the uppermost strata of the Upper White Limestone consist of beds of rubble and interstratified red shale, and occur on the top of Moelydd and Nant Mawr. They make their first appearance under the Upper Grey Limestone at Craig Sychdin, increase in thickness towards the south-~~west~~east, and can always be distinguished by the red shale and reddle associated with them. The whole of the Upper White Limestone presents a remarkable similarity to the same subdivision at Porth-y-waen and Llanymynech Hill, for at each of these places the strata are much alike, and extensive quarries are worked on the precipitous flanks of steep hills, the limestone being exposed in vertical sections from 150 to 175 feet in height. The following is a section of the beds exposed in the large quarry facing the south, along the bottom of which a fault runs nearly east and west and brings in the Bala-beds :—

		Ft.	In.
Middle and Lower beds of the Upper White Limestone.	White Limestone, with red streaks	25	0
	Reddish Shale	0	9
	White Limestone	2	0
	Reddish Shale	1	6
	White Limestone, in thick beds, with thin partings of purple shale	125	0
	White Limestone and thin shale with Pyrites	5	0
		159	3

The strata dip about 10° E.N.E. and appear to be reddish rock, but when broken of a light cream colour. The highest bed in the section is a very variable stratum, and at a distance often appears to be a single bed, though it is usually more or less divided by a few thin partings of shale. It is persistent over the Nant Mawr and Llanymynech district, and may be designated the 30-feet bed. At the east end the dip brings this bed down near the floor of the quarry, and another fault throws the strata up to the east, where the 30-feet bed has been denuded, though it comes in again over the hill in a plantation. It may be traced half-a-mile further north, where it occurs about a hundred yards west of, and parallel with the road through Treflach Wood in the form of a low ridge, sufficiently distinct to be shaded on the Survey Map, and a quarry has recently been opened in it for road-stone. There must be a fault a little to the west of this outcrop of the 30-feet bed, for there is a small exposure of the Upper Grey Limestone about a quarter of a mile west of the road. This fault is probably the continuation of the north and south fault which throws the strata up on the east of the large quarry at Nant Mawr already referred to, but it is not shown on the Geol. Survey Map.

The underlying Bala-beds are exposed not only in a road section at the entrance of the large quarry, but are faulted against the Upper White Limestone by the east and west fault in a smaller quarry about a hundred yards to the east. Fig. 9 is a representation of the fault as

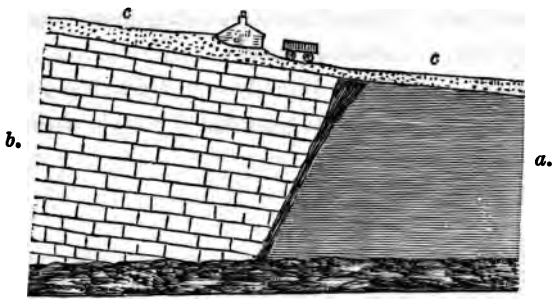


FIG. 9.—FAULT AT NANT MAWR.

c. Drift. *b.* Upper White Limestone. *a.* Bala-beds.

it appeared three years ago, but the excavating continually alters the appearance of the section from year to year.

PORTH-Y-WAEN.

The numerous quarries worked at this place afford great facility for the examination of the Upper White Limestone, which is the only subdivision that occurs in the hill. A fine view of the quarries may be obtained from the opposite hill by Offa's Dyke. From that elevation the massive 30-feet bed is conspicuous along the top of the highest quarries, but the strata gradually incline down the hill towards smaller quarries and

the road below, where it has been denuded or quarried away with some of the inferior beds. The general inclination of the strata is about 16° S.E., and the following is the section shown in the quarries:—

		FEET.
Middle and Lower beds of the Upper White Limestone.	White Limestone, often sandy & earthy	30
	Reddish Shale	3
	White Limestone in thick beds, with thin partings of purple shale ...	130
		163

Above the strata shown in this section, there are higher beds of limestone, rubble and red shale, perhaps 50 feet thick, which belong to the same subdivision and can easily be identified, though no exact succession of the beds can be made out. They occur on the highest ground above the quarries.

The lowest beds of limestone are not actually seen, but they evidently repose directly on the Bala-beds, which are exposed between the quarries and the road below. There is a quarry called the Farmer's Quarry, close to and north-east of the others, where a bed of shale 6 feet thick occurs. This shale is the same as the 3-feet bed in the section, the overlying 30-feet bed of limestone having been removed by the quarrymen. An east and west fault runs nearly parallel with the tramway above the road, and throws the strata up on the south side. It is visible in the quarry, nearly opposite the Methodist Chapel on the road below, but is sometimes *obscured* by débris at the entrance.

LLANYMYNECH HILL.

On the north-western extremity of Crickheath Hill the fault which runs through Jones' quarry nearly north and south, already referred to, has an upthrow of about 70 feet on the west side. It is not shown on the Geol. Survey Map, but it is probably much more clearly exposed now than it was twenty years ago when the district was surveyed. It exposes the Upper Grey Limestone faulted against the Upper White Limestone, as represented in following wood-cut, Fig. 10. This

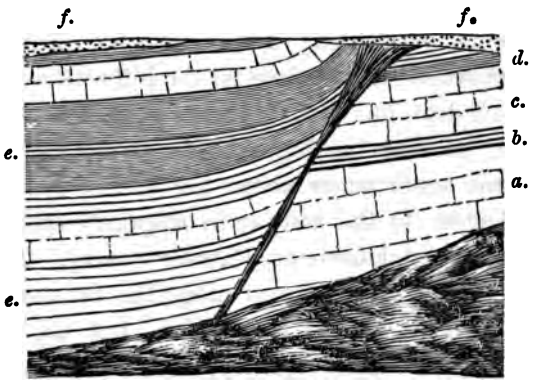


FIG. 10.—FAULT AT JONES' QUARRY.

f. Drift. *e.* Lower beds of the Upper Grey Limestone.
d. Rubble and Reddle. *c.* Limestone with Copper Ores.
b. Rubble and Reddle. *a.* Top of 30-feet bed.

fault is of importance, for the beds of the Upper White Limestone on the west or upthrow side of it are some of the highest in the subdivision, and are distinguished by very remarkable beds of reddle and small deposits of Malachite and Chalcopyrite, as shown in the following section:—

		FEET.
Upper beds of the Upper White Limestone.	*e.* White Limestone or broken rubble	3
	d. Reddle	3
	c. White Limestone, containing Malachite, Chalcopyrite, &c.	15
	b. Rubble and Reddle	4
	a. White Limestone, top of 30-ft. bed	6
		31

These upper beds of the Upper White Limestone crop out on the ascending ground above Jones' quarry, and the 30-feet bed then forms the highest parts of the hill and is continued, though denuded in places, to the precipitous escarpment overlooking Llanymynech. But towards Pant the strata as they descend the hill with a gradually increasing dip—finally 30°—to the east, have been less denuded, so that the higher beds of the Upper White Limestone again occur above the 30-feet bed, and are exposed close to the railway in a quarry opened a few years ago, and known as Eaton's quarry. There are other quarries and cuttings along the railway showing the upper beds of the subdivision, but the following section is from Eaton's quarry, which is worked at the present time:—

		FT.	IN.
Upper beds of the Upper White Limestone.	*e.* White Limestone	4	0
	e. Rubble and Shale	4	0
	d. Reddle and Purple Shale	2	6
	c. White Limestone	14	0
	b. Shale, with Malachite, &c.	4	0
	a. White Limestone, top of 30-feet bed	20	0
		48	6

Still further east of the railway and close to the canal, these upper beds of the Upper White Limestone are more completely developed, as follows:—

		FT.	IN.
Upper beds of the Upper White Limestone.	*k.* Rubble and Red Shale	4	0
	j. White Limestone	10	0
	i. Reddle	3	0
	h. Rubble and Red Shale	4	0
	g. White Limestone	1	6
	f. Rubble and Red Shale	20	0
	e. ,, and Purple Shale	7	6
	d. Purple Shale	2	6
	c. White Limestone, base not seen	10	0
		62	6

North of Pant there are several quarries on the west of the road, where the 30-feet bed and the strata immediately above it are exposed in as many different sections. The following section occurs in a quarry, not now worked, by an old limekiln, and the strata are on the same horizon as the two previous sections:—

		FT.	IN.
Upper beds of the Upper White Limestone.	*e.* White Limestone, thin bedded	10	0
	d. Reddle	0	6
	c. White Limestone	17	0
	b. Rubble and Shale	4	0
	a. White Limestone, top of 30-feet bed	17	0
		48	6

The strata shown in this and the previous sections of the uppermost beds of the Upper White Limestone, show their correlation at several places about Llanymynech Hill; and although the succession of the beds is not so clear on the hills to the north-west, the thickness

and lithological appearance seem to be very similar. At Pant they are the highest visible beds of limestone, but it seems to be a question whether they are faulted against some higher subdivision of the Carboniferous series, or whether they may not present an escarpment covered by more recent deposits.

A fine section of the Upper White Limestone is exposed on the south and south-east of Llanymynech Hill, and it is almost a continuous outcrop along the railway to the sections at Pant already described. The strata are so clearly exposed, with a regular dip of 12°, N.E.N., that the succession and thickness of limestone can be easily determined. Llanymynech Hill was originally a precipitious escarpment, but quarrying operations during the last fifty years have produced a grand rocky wall about half-a-mile in length, and the strata exposed form one of the finest mural sections in North Wales. The height is usually about 170 feet, and the beds can be seen as they lie one above another like courses of masonry. The highest cliff at the side of the round quarry, at the southern end of the hill, is 175 feet above the base, and being vertical it represents the thickness of the limestone, with the exception of a few feet below the bottom of the quarry. The following is a section of the strata exposed:—

		FEET.
Middle and Lower beds of the Upper White Limestone.	White Limestone, often sandy.....	20
	White Limestone, oolitic and shelly	7
	,, ,, flaggy beds	2
	,, ,, thick-bedded, with purple shales...	150
	,, ,, sometimes sandy..	5
		184

The upper portion of the 30-feet bed is somewhat denuded, the highest remaining part being of a sandy character, and occurs only at the edge of the round quarry at the southern termination of the hill, having been denuded further north; but the oolitic and shelly limestone extends along the top of the other quarries. The upper part of the 30-feet bed is taken off by the quarrymen and the stone thrown on the top of the cliff as useless, except as road-stone; while the oolitic and shelly portion is also left on the top in large heaps, for if thrown down to the floor of the quarry, 170 feet below, it is so shattered and broken up as to be of little value.

The Llanymynech limestone is chiefly used for fluxing purposes, and is sent away by railway to the iron smelting districts, though a large quantity is sent by canal for burning elsewhere. At Nant Mawr and Porth-y-waen a larger proportion is burnt for lime at the quarries. The general similarity of the limestone at these places has already been referred to, but the 30-feet bed at Llanymynech is not so distinctly visible as at Nant Mawr and Porth-y-waen, for there is no prominent bed of shale separating it from the inferior beds, and it is usually considerably reduced in thickness by denudation. It can, however, be easily identified above the round quarry, and its oolitic and shelly base traced along the top of the continuous line of quarries which extends to the north-east. It may also be traced through the quarries about Pant, and in those on the railway until the limestone becomes covered with drift deposits. The fossils that occur in the 30-feet bed at Llanymynech are of considerable interest, for some of them have not been found anywhere else in the district, and others not even in North Wales. They occur

in the oolitic and shelly portion, which has not been observed at the base of the 30-feet bed at Nant Mawr, or Porth-y-waen. The fossils in the lower beds seem to be of the same species in the three localities, so that the list refers to those found in all those places, though principally collected at Llanymynech. The oolitic structure referred to is not so perfect as that of the Carboniferous Limestone at Clifton, on the banks of the Avon, for the little concretions are mixed up with shelly fragments of various organisms and Foraminifera.

LIST OF THE FOSSILS FOUND IN THE UPPER WHITE LIMESTONE AT LLANYMYNECH.

1 *Cochliodus oblongus.* Ag.
2 *Patalodus Hastingia,* Owen.
3 *Bellerophon cornu-arietes,* Sow.
4 ,, *tenifasia,* Sow.
5 *Eulima Phillipsiana,* Koninck.
6 *Euomphalus,* sp.
7 *Macrochilus imbricatus,* M'Coy.*
8 *Murchisonia striatula,* Koninck.*
9 ,, *verneuliana,* M'Coy.
10 *Solarium planorbe,* Koninck.*
11 *Cypricardia striato-lamellosa,* Koninck.*
12 *Productus cora,* D'Orb.
13 ,, *comoides,* Sow.
14 ,, *fimbriatus,* Sow.
15 ,, *giganteus,* Mart.
16 ,, *longispinus,* Sow.
17 ,, *punctatus,* Mart.
18 ,, *semireticulatus,* Mart.
19 *Spirifera bisulcata,* Sow.

* Found in the 30-feet bed at Llanymynech only.

20 *Spirifera cristata*, Schloth.*
21 ,, *glabra*, Mart.
22 ,, *striata*, Mart.
23 *Streptorhynchus crinistria*, Phil.
24 *Terebratula hastata*, Sow.
25 *Rhychonella pleurodon*, Phil.
26 *Fenestella membranacea*, Phil.
27 *Griffithides longiceps*, Portl.
28 *Alveolites septosa*, Flem.
29 *Clisiophyllum*, sp.
30 *Lithostrotion Martini*, M. Edw.
31 *Syringopora reticulata*, Phil.
32 *Zaphrentis cylindrica*, Scouler.

LOWER SHALE,
OR
LOWER WHITE LIMESTONE OF LLANGOLLEN.

It has been shown that the Upper White Limestone rests directly on the Silurian strata at Nant Mawr and Porth-y-waen, and probably it does so at Crickheath Hill. However, at the east of Llanymynech Hill, in the quarry at the end of the tramway close to the "Cross Guns," some inferior strata crop out from under the limestone and represent the Lower Shale, as in the following section:—

		FT.	IN.
Lower Shales, or Lower White Limestone of Llangollen.	Dark Grey Shale	2	0
	White Limestone	4	0
	Grey and Red Shale, with bands of sandy limestone, the base not exposed	10	0
		16	0

* Found in the 30-feet bed at Llanymynech only.

Another section of the Lower Shale was discovered by Messrs. Savin & Co., 13 years ago, in sinking a shaft about 50 yards north-east of the field "63" on the 25-in. Ordnance Map, for the particulars of which I am indebted to Mr. J. Lester, of Pant, the strata in the following section being immediately under the limestone, the base of which can be seen at the place.

		FT.	IN.
Lower Shale or Lower White Limestone of Llangollen.	Soft Red Shale	13	6
	Sandy Limestone	1	6
	Soft Red Shale	6	0
	Sandy Limestone	1	6
	Hard Red Shale	40	0
		62	6

The débris around the shaft still remains with a depression in the centre, and consists of weathered red shale containing many rounded fragments of Silurian rock, exactly similar to those common in the shale-bed below the *thick-bed* of limestone at Llangollen. From Mr. Lester's description of the strata, it appears that the Bala-beds were not reached, but that the lower beds of shale were much tougher and harder than those near the surface. Lower down on the side of the hill the soil is of a red colour, and probably the Lower Shale crops out along the west and south end of Llanymynech Hill, though obscured by the limestone débris from the cliffs above, and the quarries and numerous shafts on the hill side.

The final results derived from the foregoing sections prove the thickness of the Carboniferous Limestone at the several places described, and the maximum at its southern termination at Llanymynech Hill. It has been proved

that the Upper Grey Limestone rests on the Silurian rocks from Fron-y-Cysyllte to Craig Sychdin, a distance of seven miles; and that from the latter place southwards, the Upper White Limestone underlies and continues below it, resting on the Bala-beds as far as Crickheath Hill. Further south at Llanymynech Hill a still lower series, the Lower Shale, comes in below the Upper White Limestone, and forms the lowest subdivision. The thickness of the whole of the Carboniferous Limestone about Crickheath and Llanymynech Hill is as follows:—

SUBDIVISONS OF THE CARBONIFEROUS LIMESTONE AT LLANYMYNECH HILL.

	FEET.
Upper Grey Limestone	125
Upper White Limestone	250
Lower Shale, or Lower White Limestone.....	75
	450

If the Sandy Limestone, 75 feet, were added to the Carboniferous Limestone, instead of being included in the Cefn-y-Fedw Sandstone, the thickness would be increased to 525 feet; and it is a question as to which formation should include it, for it is subject to constant lithological changes, and is rarely exposed. The thickness of the Lower Shale certainly exceeds the 62 feet 6 inches shown in the section, and has been provisonally made 75 feet.

Reviewing the subdivisions in the order of deposition, and describing them from the south toward the north, it appears that the earliest Carboniferous deposit at Llanymynech was a series of shales, which gradually became interstratified with thin bands of limestone and

formed the Lower Shale. This subdivision became gradually overlapped by the Upper White Limestone, which seems to have filled all the minor inequalities of the underlying rocks, and finally the deeper part of the sea bottom; when the deposition of the Upper Grey Limestone succeeded, and not only covered the whole of the Upper White Limestone, but a much wider area of shallow sea with a very uniform series of strata.

FAULTS AND MINERAL VEINS.

All the faults shown on the maps of the Geological Survey representing the country between Llangollen and Llanymynech, run in an east and west direction, or a little to the north of east. They are important faults, whose influence on the strata and the contour of the ground is obvious, although they can seldom be actually seen. With a single exception, all these faults are up-throws on the south, and in consequence of the easterly dip of the strata, the Carboniferous Limestone and overlying Cefn-y-Fedw Sandstone are both carried gradually further to the east, on the up-throw or south side of the fault, than they would otherwise have been. The fault with an up-throw to the north is at that end of Mynydd Myfyr—a Cefn-y-Fedw Sandstone hill—which is bounded by the Upper Grey Limestone, except on its eastern side.

The only mineral veins indicated on the Geol. Survey Map are two at Moelydd, north-west of Nant Mawr, the direction of both being east-south-east and west-north-west; and another at the south end of Llanymynech Hill north-east-north and south-west-south, from which it might be inferred that the area was not a mining district. It does not appear that any mineral veins have been discovered in the northern portion of the area, but *at Moelydd*, Crickheath, Pant, and on Llanymynech Hill,

it is evident that mining operations for copper and lead have been in progress from remote ages, and probably during distant periods. It is difficult to ascertain what amount of success, if any, attended mining in the district during former periods; but the indications of mineral wealth are so remarkable as to present strong temptations to search for the copper ore which is of such frequent occurrence in the upper beds of the Upper White Limestone. In and about the bed, *c*, in Jones' quarry (Fig. 10), Eaton's quarry, and in some of the old quarries on the west of the road at Pant, the quantity of this ore, in the form of blue and green Carbonate of Copper, is very remarkable. It is not unusual to see a heap, enough to fill a wheel-barrow, in these quarries, so that the indications of ore are favourable enough to promise success by regular mining operations. In Jones' quarry the ore is in open joints in the bed, *c*, in Eaton's it occurs in the shale bed, *d*, and in a fissure or lode through the bed *c*, and in other quarries it occurs on the same horizon. It is only in these beds that the ore is so abundant, and they are of very limited extent, having been denuded from the high ground as already described. In lower beds of the Upper White Limestone in quarries near the "Cross Guns" copper-ore occurs in limited nests of shale which fill hollows between the beds of limestone. Galena and other ores of lead, as well as Blende, have been obtained in many places, but do not appear so frequently in the rocks near the surface.

Recently Mr. Joseph Henderson, Mining Engineer, has been engaged in surveying and developing the mineral resources of Crickheath and Llanymynech Hill, under the direction of Messrs. R. and C. Gill. He has very kindly given me access to an elaborate mineral map

of the district, a verbal account of its mining history, and the general result of his explorations, all of which I take this opportunity of acknowledging.

Mr. Henderson has carefully surveyed the district and laid down the lodes that have been worked at different periods, with others that he has discovered himself during the progress of his mining operations, from which it appears that the numerous lodes vary considerably in importance, some being mere open joints and others considerable faults. The fault or lode through Jones' quarry, Fig. 10, is shown on the map running N. 14° W., some old shafts being upon it, and lead is supposed to have been obtained. The principal lode at the south of Llanymynech Hill runs N. 38° and then 32° E., and terminates at the marshy ground in the hollow, west of the Entrenchments, "2," on the 25-inch Ordnance Map. There are several old shafts along the line of the lode, from which lead is said to have been obtained. A little to the west of the termination of this lode there are evidences of old surface workings to be seen, and Mr. Henderson considers them to be of Roman origin, for two ingots of copper were obtained there, with the name of the Emperor Hadrian cast on them. Just beyond, to the north, along the edge of the cliff known as Blodwel Rocks, there are many evidences of surface work to be seen, and the direction of the lodes can be ascertained. About Crickheath Hill on the north-east there are several shafts, and the mines have evidently been worked at a more recent date—perhaps forty or fifty years ago. It is improbable that any of them are deep, or that they exceed 200 feet, at which depth the base of the Limestone would usually be reached from the top of Crickheath or Llanymynech Hill.

There is nothing very remarkable in the direction or relative age of the lodes. There are many that run about north-east and south-west which are crossed and thrown off their courses by others running about north-west and south-east, and consequently of later origin—except on the west of the hill, where the reverse is the order of dislocation, so that there is no general order of formation observable. There are, however, three important and nearly parallel lodes, known as the North Lode, running W. 24° S. hading N.; the Main Lode, W. 24° S. hading S.; and the South, or Llanymynech Lode, W. 15° S. hading S., which appear to cut and throw out all the veins they intersect, and consequently are the most recent in the district.

None of the lodes are important faults, except that shown in Fig. 10; and the amount of dislocation is of trifling extent, the one referred to being the only fault which brings down the Upper Grey Limestone against the Upper White Limestone, and there are many that are mere fissures with no throw whatever.

Mr. Henderson is driving two levels, one under Crickheath and another on Llanymynech Hill which will intersect several lodes if continued a sufficient distance, and by that means he will ascertain whether the deposits of copper and lead ores supposed to have existed near the surface are continued at a greater depth. No doubt this information will be soon obtained, and it is to be hoped that success will be the result of the skill and capital employed.

The following minerals occur:—Blende, Calamine, Calcite, Cerussite, Chalcopyrite, Chessylite, Galena, Hæmatite, Malachite, Pyrolusite, Pyromorphite, and Quartz.

MINERA.

The Carboniferous Limestone and Cefyn-y-Fedw Sandstone between the Eglwyseg ridge and Minera have now to be described, and the formations retain their interest as they approach the northern limit of the country under description. The precipitous scars of Craig Arthur, Craig Aderyn, and Craig-y-Forwyn are all within two miles from the Ty-nant ravine, and are well worth a visit on account of the majestic grandeur of their outlines. They all present similar sections to Craig-yr-ogof, the Lower Brown Limestone forming the base, with the higher subdivisions in regular ascending order and overlying them towards the east. There is a deep ravine between Craig Aderyn and Craig-y-Forwyn, and an east and west lode was recently worked in it for lead. In front of the ravine the Bala-beds crop up from under the Wenlock Shale and rapidly rising form the mountain Cyrn-y-Brain, the Carboniferous Limestone resting on its eastern slope. The Bala-beds ascend so rapidly towards the north that the Lower Brown Limestone suddenly ends, and both it and the Lower White Limestone are overlapped by the Upper White Limestone, within half a mile north of the ravine. The latter subdivision continues exposed for about a mile, presenting a succession of low terraced ridges along the heathy and fern-clad surface, the rock having the usual compact structure. Further on, there is a long valley between the Bala-beds of Cyrn-y-Brain and the Carboniferous Limestone; the highest ground on the east being the Lower Cefn-y-Fedw Sandstone and Conglomerate. This valley is very deeply covered with drift, so that the underlying strata cannot be seen, and it continues so until near Minera, where a deep transverse valley exposes a grand section through the Carboniferous Limestone and Cefn-y-Fedw

Sandstone—the base of the former being exposed as it rests on the underlying Silurian in the bed of the stream which flows down the valley towards the east. The precise direction of the valley from the west is east-north-east for half a mile, when it runs east-south-east for about a mile. The source of the stream, or River Clywedog, is on the eastern flank of Cyrn-y-Brain and it flows by Minera, south of Wrexham into the Dee. The Upper White Limestone comes in over the Bala-beds along the course of the Clywedog, where it flows north. Near Ty-hir, about a hundred yards east of the spot where the stream receives a tributary and turns round to the east, the lowest beds of the limestone are exposed, overlying the vertical Bala-beds, and again about a quarter of a mile lower down the latter rise and form a ridge for about fifty yards across the bed of the stream. A little further on in the quarry they were found below the tramway, when they finally disappeared. At the Hush Mine, a quarter of a mile to the north, the Silurian rock occurs at the bottom of the shaft 135 feet below the surface, that thickness of the Upper White Limestone reposing on it. All the limestone along the upper course of the Clywedog belongs to the Upper White Limestone, and at its greatest thickness is about 160 feet. It is succeeded by the Upper Grey Limestone on both sides and lower down the stream towards Minera. The lowest beds of the Upper White Limestone are composed of beds of compact white limestone containing numerous pebbles of various sizes, from that of a pea to some two inches in diameter, composed of quartzite and other hard rocks probably derived from the underlying Silurian strata.

The Upper White Limestone is of a very uniform character, though it does not present such a compact structure as in some of the southern localities. It is a

thick-bedded limestone, separated by mere lines of shale, though between the lowest and highest beds they approach a foot in thickness. There are extensive quarries worked on both sides of the river, and those on the south belong to the Minera Lime Co. The Secretary, Mr. J. A. Broadbent, and the Manager, Mr. J. Jones, gave me all the information and rendered all the assistance they could when surveying the district. During the progress of excavating, old shafts and levels driven along the lodes are continually brought to light, for several faults cross the quarries, and one of them, the Ragman vein, running north-west and south-east, with a down-throw of about 60 feet on the south-west, brings the Upper Grey Limestone against the Upper White Limestone at the end of the large quarry above the office of the Company. In the same quarry a fine mural section exposes about 70 feet of the Upper Grey Limestone resting conformable on 80 feet of the Upper White Limestone, so that the gradual change from typical beds of the one to those of the other can be examined, and there is not a more interesting section between Minera and Llanymynech. The highest bed of the Upper White Limestone is a compact light-coloured rock, 17 feet thick, with a bed of rubble about a foot thick over it, which separates it from a coarse-grained light grey bed overlying it, succeeded by a thin bed of black shale and then by a dark grey limestone—typical of the Upper Grey Limestone.

Minera Hill is the northern termination of Fron Deg, which is the continuation of Cefn-y-Fedw, and rises to an elevation of about 500 feet above the Clywedog. The range ends with a steep escarpment at Minera, where the strata have been abruptly cut off and thrown down by the Minera fault several hundred feet. The strata

present a very uniform dip of about 8° towards the south-east. There are several quarries, mine heaps from shafts, and levels driven into the hill, so that the succession of the beds is particularly well exposed. Along the top of the hill, opposite the village of Minera, there is a bold and precipitous ridge, which forms a conspicuous object even at Wrexham, four miles off. The ridge is divided by an indentation where the rocks have broken down about the middle, and the two lines of cliff are known as Craig Fechan on the east and Craig Mawr on the west, the latter exposing the strata in a section where every bed of the Sandy Limestone and the highest beds of the Upper Grey Limestone may be examined. The quarries worked at the extreme west of Minera Hill are in the Upper White Limestone, and there are others higher up on several horizons in the Upper Grey Limestone, the rocky ridge of Sandy Limestone just described being above them, while the Lower Cefn-y-Fedw Sandstone and Conglomerate forms the still higher background of the hill. The latter is seldom actually exposed, but is represented by thousands of large angular stones, which crowd the hill far below the actual base of the subdivision, and usually cover the outcrop of the Sandy Limestone, which from its softer character has been more rapidly denuded. The following is a general section of the whole of the strata exposed at the end of the hill.

SECTION OF CARBONIFEROUS STRATA EXPOSED IN MINERA HILL.

		FEET.
Lower Cefn-y-Fedw Sandstone and Conglomerate.	*k.* White Sandstone, with quartz pebbles.....	100?

Sandy Limestone...	*j*. White Sandstone, with concretions of limestone	30
	i. Grey Limestone, solid bed.....	11
	h. Yellow Sandstone, graduating into limestone at the top and bottom	12
	g. Shale, with beds of limestone, 8 or 9 in. thick	18
		71
Upper Grey Limestone.	*f*. Grey Limestone, massive bed..	35
	e. Grey Shale, with bands of limestone	20
	d. Grey Limestone, thin bedded..	25
	c. Black Shale.....	25
	b. Grey Limestone, thick bedded, with black bands.....	100
		205
Upper White Limestone.	*a*. White Limestone, thick beds...	160
	Total	536

The subdivisions into which the strata are divided may be easily identified and examined, and especially the Sandy Limestone at the top of Craig Mawr and Craig Fechan, just above the office and other works of the Minera Mining Co. The strata forming the 30-feet bed, *j*, of the Sandy Limestone at the top of Craig Mawr and Craig Fechan, with the beds below, altogether about 71 feet in thickness, may be considered a typical example of the subdivision—the white sandstone with numerous concretions of limestone of a lenticular shape,

resembling the chert nodules in the Upper Grey Limestone at Mold and other places. The concretions contain fossils, and there are casts of them in the sandstone itself, which will often effervesce in acid. *Chonetes Hardrensis* and *Productus longispinus* were found in the concretionary limestone nodules. The massive 35-feet bed, *f*, at the top of the Upper Grey Limestone is well exposed along Craig Mawr, but the 20-feet of shale with bands of limestone, *e*, is only visible in a water-course, which runs down the hill, and must be always dry, except in very wet weather, for it descends the steep slope of the hill. It can be examined in the bed of the water-course below the limestone at the entrance to an arched level driven into the hill, the limestone there exposed being the base of the 35-feet bed, a fault or land-slip having brought it down to a lower level. The lower 25-feet bed of shale, *c*, above the 100-feet of grey limestone, *b*, is conspicuous in two quarries nearer the Minera quarries, with the thin bedded limestone, *d*, resting on it.

The ridges and terraces along the slope of Minera Hill, near the Upper White Limestone quarries, well deserve attention, for they indicate the outcrop of the successive strata with remarkable exactitude, whether seen from the opposite Berwig Mountain, or on the ground itself. The two beds of shale, *e*, and *c*, are each represented by terraces, with the thin bedded limestone, *d*, forming a ridge between. The thickness of the grey limestone, *b*, was measured from the ridge at the top of it down to its base where exposed in the quarry below.

LIST OF FOSSILS FOUND IN THE UPPER GREY LIMESTONE AT MINERA.

1 *Aviculo-pecten micropterus*, M'Coy.
2 *Athyris ambigua*, Sow.
3 ,, *Royssii*, Léveille.
4 *Orthis Michelini*, Koninck.
5 *Productus cora*, D'Orb.*
6 ,, *giganteus*, Mart.
7 ,, *latissimus*, Sow.
8 ,, *longispinus*, Sow.
9 ,, *semireticulatus*, Mart.
10 *Spirifera crassa*, Koninck.
11 ,, *bisulcata*, Sow.
12 *Poteriocrinus crassus*, Koninck.
13 *Alveolites septosa*, Flem.
14 *Cyathophyllum Murchisoni*, M. Edw.
15 ,, *regium*, Phil.
16 *Clisiophyllum turbinatum*, M'Coy.
17 *Lithostrotion ensifer*, M. Edw. †
18 ,, *irregulare*, M'Coy.
19 ,, *junceum*, Flem.
20 ,, *Portlocki*, M. Edw.
21 *Lonsdaleia rugosa*, M'Coy.
22 *Syringopora geniculata*, Phil.
23 *Zaphrentes cylindrica*, Scouler.

---

* Occurs also in the Upper White Limestone, but it is the only species I was able to determine, fossils being remarkably scarce in the subdivision at Minera.

† A single specimen, the only one I have so far found in North Wales.

Foraminifera seem always present in the Carboniferous Limestone, except, perhaps, in the Lower Brown Limestone. Mr. G. W. Shrubsole, F.G.S., found beautifully weathered specimens of *Saccammina Carteri* in a black bed about the middle of the lowest 100-feet of the Upper Grey Limestone at Minera, with the following additional species:—*Trochammina incerta*, D'Orb; *Endothyra Bowmani*, Phil; *Endothyra ammonoides*, Brady; *Valonlina palæotrochus*, Ehren.; *Valonlina decurrens*, Brady; *Archædiscus Karrari*, Brady.

FAULTS AND LODES.

The faults exposed in the quarries in the limestone in the country about Minera are all regarded as lodes, or mineral veins, and the numerous shafts sunk over and the levels driven along them prove that they are identical. The principal lodes laid down on the Geol. Survey Map are also the principal faults, and the most general direction is about north-west and south-east. The Minera vein, the great fault or lode which throws the Carboniferous Limestone up on its south-west side, is evidently the most important dislocation, and is supposed to extend nearly five miles.

Capt. J. Ball, of Minera, informed me that the Silurian rock occurs at the depth of 870 feet from the surface in the Minera Mine, which is in the valley, the overlying Carboniferous Limestone and Cefn-y-Fedw Sandstone being nearly that thickness, for the general dip of the strata is only 8°, but it is so long since any shaft was sunk that he could not give the thickness of the sandstone which overlies the limestone. Capt. S. Mitchell has, however, given me the following section of the strata passed through in sinking No. 3 Shaft at the Park mine, on the top of Minera hill. The position of the shaft is close to the letter "P" in the word "Pen-y-Craig," apparently in the Lower Cefn-y-Fedw Sandstone, and ending downwards at the Minera upper day-level, 235 yards below the surface.

		FEET.
Cefn-y-Fedw Sandstone and Sandy Limestone.	? Coal-measures	90
	k. Millstone Grit, including thin beds of sand, clay, & shale...	279
	h, *i* & *j*. Dark Limestone	82
	g. Chert	21

Upper Grey Limestone.	*f.* Dark Limestone	32
	e. Limestone with thin shale beds	30
	d. Dark Limestone	51
	c. Black Shale	21
	b. Dark Limestone, to adit level...	99
	Total depth of Shaft.....	705

The strata agree closely with those given in the section of strata exposed on the escarpment of the hill, especially considering that the sections are about half a mile apart, so that a change in the beds would be likely to occur. The letters in italics show the correlation of the strata in the two sections; the Minera upper day-level being near the base of the Upper Grey Limestone. The supposed Coal-measures at the top of the section require investigation, but as the shaft was sunk many years ago, and the strata are not visible on the surface, it is difficult to give an opinion about them; probably they belong to the Middle or Upper Cefn-y-Fedw Sandstone and contain two thin seams of coal as reported, perhaps correlating with the coal seams on the east of Cefn-y-Fedw and Mynydd Myfyr already described. If ever the strata are proved to be Coal-measures it will be time enough to endeavour to explain their occurrence in such an unexpected position, and whether introduced by faults, or proving some unconformity between them and the underlying Lower Cefn-y-Fedw Sandstone.

The Minera fault running north-west and south-east along the valley brings in the Cefn-y-Fedw Sandstone, and forms the hill known as Berwig mountain. The longest direction of the hill is about north-west and north-east, which nearly coincides with the strike of the strata exposed in several quarries. The highest strata closely

resemble the Aqueduct Grit of the typical locality, especially at the Minera quarry near the church, worked by Mr. R. A. Rylands, where the coarse grit is a good building stone. This, and another quarry in similar rock, are assumed to be about six or seven hundred yards from the Coal-measures, but the intervening space is all cultivated, so that little or nothing is known about it. The lower beds are of a yellow colour, very much false-bedded, and crop out at Cae-fadog, but there is no black shale associated with them, which might have been expected if on the horizon of the Dee Bridge Sandstone near Llangollen, and below that of the Aqueduct Grit. Probably a fault occurs on the north-west of Berwig mountain, being a continuation of three mineral veins which meet at a point south-west-south of the Bwlch-gwyn mining ground, so that the middle beds of the Cefn-y-Fedw Sandstone, including the Cherty Shale, are not exposed at the surface. The Horizontal Section, Sheet 44, of the Geol. Survey, passes through Bwlch-gwyn. There is no such fault represented, but the thickness of the Millstone Grit (Cefn-y-Fedw Sandstone) is shown to be nearly 1,000 feet; and the Carboniferous Limestone 1,200 feet, whereas in the foregoing sections the latter is proved to be only 436 feet including the Sandy Limestone, which was probably included by the Surveyors.

The Lower Cefn-y-Fedw Sandstone and Conglomerate crops out at Bwlch-gwyn and other localities on the north-east, along the course of the Bala fault. The rock is a well-known local stone, as it is extensively used for repairing the roads, for which purpose it is very suitable. Originally it seems to have been a fine grained sandstone, but with occasional beds of conglomerate interstratified with it. Mostly it has been converted into

quartzite, and some of the finer beds into chert, which often contains chalcedony. Small crystals of quartz occur along the joints with earthy Sulphate of Lead; which is so common that a large proportion of the road-stone is coated with this yellow mineral, and the stems of encrinites occur in the form of *screw-stones*.

CONCLUSION.

The great Bala fault, which runs from the south-west to the north-east, forms the northern boundary of the Carboniferous rocks in the country between Llanymynech and Minera, and the uniform character of the subdivisions is remarkable over the whole area that has been described. The identification of the subdivisions of Carboniferous Limestone and the Cefn-y-Fedw Sandstone has resulted in proving the varying thickness of the former along the country described, while the latter formation presents remarkable uniformity. The lowest subdivisions of the Carboniferous Limestone, the Old Red Sandstone, and the Lower Brown Limestone only occur in the deepest hollows, and represent the most ancient Carboniferous deposits. The Upper Grey Limestone, however, extends over the whole area, and no doubt once extended far and wide over the Silurian rocks beyond its present boundary. The Cefn-y-Fedw Sandstone seems invariably to have succeeded the deposition of the Upper Grey Limestone, but it is impossible to define its extent before the great denuding influence set in, which produced the extended escarpment along its western termination.

The Bala fault throws down the Cefn-y-Fedw Sandstone on the north-west, and presents a series of geological phenomena between Llandegla and Ffrith which are of considerable interest, though they can be only described in a very brief manner. Between Llandegla and Minera the fault seems to be a double-fault, with the Upper Grey

Limestone between the two lines of dislocation. At Hafod-dafalog the road passes over the latter subdivision, which is quarried for roadstone, the strata inclining at various angles, as might be expected when faulted between the Bala-beds on the one side and the Cefn-y-Fedw Sandstone on the other. Nearer Minera the narrow ridge of limestone is conspicuous along a portion of the old Llandegla road as shown on the Geol. Survey Map. As the fault runs below Bwlch-gwyn the Sandy Limestone occurs, and can be seen on both sides cropping out from under the Lower Cefn-y-Fedw Sandstone. Still further north-east the Sandy Limestone is again presented under similar conditions, but with its continuity along the main fault broken by small cross-faults. Gwern To is a grand old hill of Cefn-y-Fedw Sandstone on the north-west of the fault, with the Sandy Limestone at its base, faulted as described, and presenting a precipitous cliff above the stream in the valley; for the fault, the valley, and the stream follow the same course. On the south-east of the fault there are several mineral veins where mining operations have been in progress. The direction of the veins is at a considerable angle to those at Minera, the principal running into the Bala fault. The veins have been worked in the Lower Cefn-y-Fedw Sandstone or Bwlch-gwyn rock, which, according to several miners, is about 180 feet thick. Between Bwlch-gwyn and Llandegla there are frequent trial-pits, though they seem to have been abandoned after short trials. The country to the north-west of the Bala fault rises rapidly and is of a mountainous character, being Cefn-y-Fedw Sandstone with the Carboniferous Limestone cropping out and presenting its usual subdivisions, including the Lower Brown Limestone, towards Llandegla and Llanarmon, but all at a lower level.

The number of fossils found in the Carboniferous Limestone between Llanymynech and Minera, and given in the foregoing lists, amounts to 106 species. The greatest number of these occurs in the Upper Grey Limestone, and there is a remarkable similarity between those found in the various localities. A few species are represented by single specimens, while some, common in one or two places, are altogether absent in others. Comparatively few of the species occur in the lower subdivisions, probably because the conditions were unfavourable for their preservation, and it is improbable that they did not exist in the area during the deposition of the whole of the limestone. A tabulated list showing the range of the species over the entire area might have been interesting, but it would have been of such a provisional character as not to have been of permanent value. However, the general result of such a list would have been similar to the tabulated list of the typical locality at Llangollen where the most thorough search for fossils was made (page 299), except that a greater number of peculiar species would appear in the Upper White Limestone, as shown by the rare forms found in that subdivision at Llanymynech. Further search will no doubt add to the foregoing lists, but the Upper Grey Limestone will always present the greatest number, though additional species may be found in the lower subdivisions.

The fossils of the Cefn-y-Fedw Sandstone, with the exception of the plants, seem to be of the same species as those in the Carboniferous Limestone; some of the most common being found at Tyfyn-uchaf, in the Lower Shale, near the highest beds in the formation.

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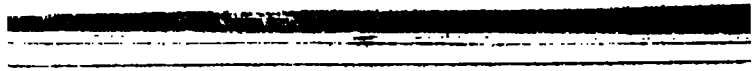
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